AD NUMBER	
AD506594	
CLASSIFICATION CHANGES	
TO:	unclassified
FROM:	confidential
LIMITATION CHANGES	
TO:	Approved for public release, distribution unlimited
FROM:	
AUTHORITY	
Jan 1982, per document markings, DoDD 5200.10; AFPRL ltr, 5 Feb 1986	

(TITLE UNCLASSIFIED)
REUSABLE SUBSYSTEMS DESIGN/ANALYSIS STUDY

Vol II, Part B – Technical Study Report

L. L. Morgan

CONFIDENTIAL

AFRPL-TR-69-210
Vol II, Part B

(TITLE UNCLASSIFIED)
REUSABLE SUBSYSTEMS DESIGN/ANALYSIS STUDY

Vol II, Part B – Technical Study Report

L. L. Morgan
Lockheed Missiles & Space Company

TECHNICAL REPORT AFRPL-TR-69-210, Vol II, Part B
January 1970

Air Force Rocket Propulsion Laboratory
Air Force Systems Command
Edwards Air Force Base, California

CONFIDENTIAL

FOREWORD

The study summarized in this presentation was conducted by Lockheed Missiles & Space Company (LMSC) for the Air Force Rocket Propulsion Laboratory, Edwards, California, under contract F04611-69-C-0041. The study was under the technical direction of Mr. David T. Clift, Propulsion Subsystems Branch, Liquid Rocket Division, and Lt. George T. Reed, Analysis and Applications Branch, Liquid Rocket Division. The study technical effort has been conducted between the period from December 1968 to July 1969.

The study report is published in the following four volumes:

Volume I – Management Study Summary
Volume II – Technical Study Report
Volume III – Supplemental Data (Appendixes)
Volume IV – Special Supplemental Data

NOTE: Because of its size, Volume II is bound in two separate books: Part A contains Sections 1 through 5; Part B contains Sections 6 through 9. Both Part A and Part B contain a full table of contents, for the convenience of the reader.

Classified information has been extracted from those documents marked with an asterisk in Section 9, Volume II, Part B (References).

Major contributors of the study were as follows:

L. L. Morgan – Study Manager
R. L. Gorman – Component Engineering
H. L. Jensen – Subsystem Engineering
R. F. Hausman – Accessibility and Subsystem Tradeoff Studies
H. K. Burbridge – Reliability Studies
C. V. Hopkins – Advanced Technology Programs
K. Urbach – Subsystems Checkout
R. M. Bonesteel – Fracture Studies
R. W. Lewis – Fracture Studies
Y. Yoshikawa – Thermodynamics

This technical report has been reviewed and is approved.

David T. Clift
AFRPL Project Engineer

CONTENTS

ILLUSTRATIONS

TABLES

Section 6
REUSABILITY OF EXISTING HARDWARE (U)

(U) The determination of the applicability of existing hardware for expendable vehicles to requirements in the reusable vehicles was given a major emphasis in this study. Particular attention was given to the identification of candidate components for which adequate performance information was available as the result of actual usage on current or past propulsion subsystems. This effort required the participation of component manufacturers and suppliers of aerospace components. The attention given by these companies to this study, and the responses received contributed significantly to the results. A considerable quantity of technical effort and assistance was contributed by these manufacturers and suppliers. Acknowledgement of the participation of these contractors is presented in the foreword, and is repeated in Table 6-1.

6.1 OBJECTIVES AND SCOPE (U)

(U) The objectives of these related activities were to determine the applicability of existing hardware to satisfy the subsystem and component requirements established for the propulsion subsystems of the reference vehicles.

(U) The performance of the task required the consideration of three major subtasks.

6.1.1 Examination of Subsystem Components (U)

(U) Existing component information was evaluated so as to determine if the components applicable to each of the subsystems were capable of the required

number of reuses with no further development work required; or were capable of qualifying for the required number of reuses with some development work utilizing existing or anticipated technology; or were incapable of qualifying for the specific number of reuses unless some unforeseen breakthrough in technology is achieved.

6.1.2 Determination of Necessary Component Accessibility (U)

(U) Investigations were conducted to determine the components that need to be accessible for servicing or replacement. These investigations also indicated the components with the most severe lifetime problems.

6.1.3 Qualification of Components and Subsystems (U)

(U) Examinations were made of the principal general specifications related to qualification of subsystems and components to determine desirable changes or additions to these specifications to increase their applicability to reusable subsystems.

Table 6-1

COMPONENT MANUFACTURERS AND SUPPLIERS
ACKNOWLEDGEMENT OF PARTICIPATION (U)

Principal Contributors	Location
AiResearch, Division of the Garrett Corporation	Los Angeles, California Pheonix, Arizona
Calmec, Division of Ametek	Los Angeles, California
Parker Aircraft, Division of Parker Hannifin	Los Angeles, California
Royal Industries	Santa Ana, California
Sterer Engineering	Glendale, California
Wallace O. Leonard	Pasadena, California
Whittaker, Corporation	Chatsworth, California
Other Contributors	
Accessory Products	Whittier, California
Airite	El Segundo, California
Bell Aerosystems	Buffalo, New York
Carleton Controls	East Aurora, California
Futurecraft	Industry, California
Marotta Valve	Santa Ana, California
Moog	East Aurora, New York
Marquardt	Van Nuys, California
Purolator	Newberry Park, California
Solar Products	San Diego, California
Snaptite	Union City, Pennsylvania
Stratos Western	Manhattan Beach, California
Vacco	El Monte, California
Valcor	Kenilworth, New Jersey

6.2 EXAMINATION OF SUBSYSTEM COMPONENTS (U)

(U) The procedure employed in obtaining the necessary component information was as follows:

- Preparation of a summary of the component operating conditions regarding flowrates, temperatures, fluids, required sizes, etc., for each of the components in the subsystems presented in Section 3.
- Distribution of the component requirements to the component suppliers with the requests for candidate components. Visits were made to certain component supplier facilities.
- Examination and screening of component information provided by suppliers. Information was provided by the companies listed in Table 6-1.
- Matching of the components to the requirements.
- Examination of the information, drawings, and, in some cases, the actual components to possible modifications which were necessary or desirable for reusability.
- Conduct of literature surveys to provide additional information.

6.2.1 Results of the Examination of Subsystem Components (U)

(U) Results of examination of the subsystem components are presented in Table 6-2 through Table 6-8. The number of missions estimated for the components was obtained from the data produced in the accessibility studies presented in Section 6.3.

(U) The more important features of the components with regard to their current application and usages are indicated. The component modifications required or considered desirable are presented. In paragraph 6.2.1.4, a general discussion of characteristics is provided. The component numbers indicated in the tables are referenced to Volume IV, Special Supplement (Restricted Distribution), which provides the manufacturer name and component identification.

6.2.1.1 (C) Reusable Launch Vehicle. The information concerning the principal components of the Reusable Launch Vehicle subsystems is presented in the following tables:

Table	Information
6-2	Feed System/Ground and Flight Vent
6-3	Pressurization System • GHe Prepressurization • GHe LO_2 Pressurization • GH_2 LH_2 Pressurization • Regulator Controlled
6-4	Pressurization System • GHe Prepressurization • GHe LO_2 Pressurization • GH_2 LH_2 Pressurization • Modulated Valve Control
6-5	Pressurization System (Autogenous) • GO_2 Bleed Prepressurization • GO_2 Bleed Pressurization • GH_2 Bleed Prepressurization • GH_2 Bleed Pressurization • Regulator Controlled
6-6	Pressurization System (Autogenous) • GO_2 Bleed Prepressurization • GO_2 Bleed Pressurization • GH_2 Bleed Prepressurization • GH_2 Bleed Pressurization
6-7	Pressurant Heating for Subsystems Utilizing GHe
6-8	Attitude Control System • N_2O_4/MMH

(U) The particular subsystems were selected and approved for examination early in the study, allowing the steps involving suppliers, discussed earlier, to be accomplished.

(U) To extract conclusions from these investigations, it is necessary to consider the Accessibility Studies presented in paragraph 6.3 and the Subsystem Evaluations presented in Section 7, paragraph 7.3, which were the sources of the "Probable Lifetime" in the number of flights which are shown in the tables. Some generalizations are

(U) necessary to summarize the trends resulting from the investigations. The comments presented in Table 6-9 relate to the Reusable Launch Vehicle specifically examined in the study; however, these comments will generally apply to larger vehicles, with a few exceptions such as the size of feedline valves.

(U) It should be noted that, with the exception of check valves, most of the valves and regulators have acceptable lifetimes based upon the lifetimes estimates. If helium pressurization is used, either in prepressurization or pressurization, there will be the necessity to reduce the leakages of most of the valves.

(U) "Instrumentation" type components appear to require lifetime extensions. This includes pressure switches, pressure transducers, and liquid level devices.

(U) Additional general discussions regarding components are presented in paragraph 6.2.1.4 including such additional components as positive displacement devices, etc.

6.2.1.2 (C) Cryogenic Spacecraft (LF_2/LH_2). Since liquid fluorine represents a relatively new technology, with no flight vehicles currently in a development stage, the extent of component development to date in no way compares of the status of LO_2/LH_2 systems. A summary of the previous liquid fluorine subsystem and component developments is presented in Figure 6-1.

(C) Since most of the LF_2 components exist as prototype or conceptual designs, most of the data presented are based upon development of these into flight hardware or upon modification of existing hardware. An interesting factor in the LF_2/LH_2 stage is that few components actually contact fluorine in normal service. The pressurization system is entirely excluded with the exception of the check-valves, and possible contact with the regulator.

(U) The results of the examination of the components in the Cryogenic Spacecraft Subsystems are presented in Tables 6-10 through 6-13. As in the case of the Reusable Launch Vehicle, consideration of paragraph 6.3, Accessibility studies, and the System Evaluations in Section 7, paragraph 7.3, were necessary to produce the generalized conclusions in Table 6-14.

Table 6-2

REUSABLE LAUNCH VEHICLE FEED SYSTEM/
VENT SYSTEM COMPONENT EXA

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Env
			Gas	Liquid	M-I	M-II	
Feed System/ Ground and Flight Vent	LO_2 Shutoff Valve Provides shutoff of drop tank feedline (U20, U21)	10	N.A.	Zero	100	50	GN_2, LO_2 163°I
	LH_2 Shutoff Valve Provides shutoff of drop tank feedline (U22, U23)	12	N.A.	Zero	100	50	GN_2, LH_2 37°R
	LO_2 Prevalve (U24, U25)	4	50 to 100 (also engine valve dependent)	Zero	100	50	GN 163

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-33, Figure 3-10.

Table 6-2

FEED SYSTEM/GROUND AND FLIGHT
OMPONENT EXAMINATION (U)

ONFIDENTIAL)

ge	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
id	M-I	M-II						
	100	50	GN_2, GO_2, LO_2 LO_2 163°R to 580°R	U20-1 U21-1	Visor Valve, 10 inch LO_2 Vent 12,000 sccm Pneumatic actuator	Modification Required	Minor	(1) Leakage high (2) Actuator should stop visor inertia when closing (3) Low pressure drop (4) Light weight (5) Remove relief pilot (6) Modify actuator to cryos. temp.
				U20-2 U21-2	Swing Poppet Valve LO_2 Vent and Relief 800 sccm 10-inch Pneumatic actuator	Modification Required	Moderate	(1) Line diameter must be enlarged (2) Remove relief function (3) Heavier than visor ball (4) Low leakage
				U20-3 U21-3	Ball Valve, 12-in. RPI-SOV Pneumatic Actuator	Modification Required	Major	(1) Has dual seals (2) Seal change required (3) High seal wear – movable seals recommended (4) Modify actuator – cryos (5) Low pressure drop (6) High weight for application (7) Lower response than visor ball (8) High actuator torque
	100	50	GN_2, GHe, GH_2 LH_2 37°R to 500°R	U22-1 &23-1	Visor Ball, 12 inch RPI-SOV Pneumatic actuator	Modification Required	Minor	(1) Change seals (2) Modify to normally closed (3) Actuator should stop visor inertia when closing (4) Modify actuator – cryos (5) Leakage may be a problem for Mission II (6) Low weight, high flow capacity
				U22-2 U23-2	Ball Valve, 12-in RPI-SOV Pneumatic actuator	Modification Required	Major	(1) Change seals (2) High seal wear – movable seals (3) Modify actuator – cryos (4) High weight (5) Lower response than visor ball (6) High actuator torque
	100	50	GN_2, GO_2, LO_2 163°R to 580°R	U24-1 U25-1	Visor Ball, 4 inch LO_2 interconnect 20,000 sccm Pneumatic actuator	Modification Required	Minor	(1) Gas leakage high (2) Modify actuator – cryos (3) High flow capacity (4) Weight somewhat high
				U24-2 U25-2	Rotor Ball, 5.7 inch LO_2-SOV 300 sccm	Modification Required	Minor	(1) Actuator modification – cryos (2) High flow capacity (3) Heavy for application (4) Leakage somewhat excessive for application
				U24-3 U25-3	Butterfly Valve, 4 inch 300 sccm LH_2, LO_2 fill	Modification Required	Major	(1) Actuator modification – cryos (2) Relatively low pressure drop (3) Heavy body, must be re-designed for light weight (4) Larger than necessary (5) Leakage somewhat excessive

3, Figure 3-10.

Table 6-2 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environm
			Gas	Liquid	M-I	M-II	
Feed System/ Ground and Flight Vent (cont.)	LH_2 Prevalve (U27, 28)	4	600 to 1200 (also engine valve dependent)	Zero	100	50	GN_2, GHe, LH_2 37°R to 58(
	LO_2 Retro Tank Prevalve (U26)	4	1 to 3 (also engine valve dependent)	Zero	100	50	GN_2, GO_2, 163°R to 58
	LH_2 Retro Tank Prevalve (U29)	4	25 (also engine valve dependent)	Zero	100		GN_2, GHe, LH_2 137°R to 58
	LO_2 Drop Tank Vent Valve (U30, U31)	5	N. A.	N. A.	85	50	GN_2, GO_2, 163°R to 58
	LH_2 Drop Tank Vent Valves (U32, U33)	6	N. A.	N. A.	100	50 37	GN_2, GHe, LH_2 37°R to 58(

1

ble 6-2 (Cont.)
ONFIDENTIAL)

age	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
uid	M-I	M-II						
	100	50	GN_2, GHe, GH_2 LH_2 37°R to 580°R	U27 U28	Same as LO_2 Prevalve (U24, U25)			Essentially same as LO_2 Prevalve (U24, U25)
	100	50	GN_2, GO_2, LO_2 163°R to 580°R	U26	Same as LO_2 Prevalve (U24, U25)			Essentially same as LO_2 Prevalve (U24, U25)
	100		GN_2, GHe, GH_2, LH_2 137°R to 580°R	U29	Same as LO_2 Prevalve (U24, U25)			Essentially same as LO_2 Prevalve
	85	50	GN_2, GO_2, LO_2 163°R to 580°R	U30-1	Poppet Valve, 5 inch LO_2 Vent and Relief 1600 sccm Pneumatic Actuator	Reusable	None	(1) Close to requirements (2) Low weight and pressure drop (3) Angle valve (4) Can be pneumatically closed
				U30-2	Butterfly Valve, 6 inch RP1, GHe Vent 2500 sccm Pneumatic override	Modification Required	Major	(1) Modify for cryogenic service (2) Modify actuator – cryo (3) Heavy for application
				U30-3 U31-3	Poppet Valve, 7 inch GO_2 Vent and Relief Pneumatic Override	Reusable	None	(1) Close to requirements (2) Larger than necessary (3) Can be pneumatically closed
	100	50 37	GN_2, GHe, GH_2 LH_2 37°R to 580°R	U32-1 U33-1	Poppet Valve, 6 inch LH_2 Vent and Relief 1600 sccm Pneumatic Override	Reusable	None	(1) Close to requirements (2) Low weight (3) Pneumatically closed (4) Angle valve
				U32-2 U33-2	Butterfly Valve, 6 inch RP1, GHe Vent and Relief 2500 Pneumatic Override	Modification Required	Major	(1) Modify for cryogenic service (2) Modify actuator
				U32-3 U33-3	Poppet Valve, 7 inch LH_2 Vent and Relief Pneumatic Override	Reusable	None	(1) Close to requirements (2) Can be pneumatically closed

CONFIDENTIAL

2

Table 6-2 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environm
			Gas	Liquid	M-I	M-II	
Feed System/ Ground and Flight Vent (cont.)	LO_2 Ascent/Maneuver Tank Vent and Relief (U34, U35)	2	50 to 100	Zero	100	50	GN_2, GO_2 163°R to
	LH_2 Ascent/Maneuver Tank Vent and Relief (U37, U38)	2	600 to 1200	Zero	100	50	GN_2, GHe LH_2 37°R to 5
	LO_2 Retro Tank Vent and Relief U36	1	1-3	Zero	100	50	GN_2, GO_2 163°R to
	LH_2 Retro Tank Vent and Relief U39	1	25	Zero	100	50	GH_2, GO 163°R to
	LH_2 Feedline Coolant Shutoff Valve Provides cooling to feedlines (U40, U49)	1/4	25	Zero	100	50	GN_2, Gh LH_2 30°R to

ble 6-2 (Cont.)

(CONFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
100	50	GN_2, GO_2, LO_2 163°R to 580°R	U34-1 U35-1	Poppet Valve, 2-1/2 inch GO_2 Vent Valve	Modification Required	Minor	(1) Close to requirements
			U34-2 U35-2	Poppet Valve, 2-1/4 inch GO_2, GH_2 Vent and Relief 800 sccm Metal seat and poppet Pneumatic close	Modification Required	Moderate	(1) Leakage high (2) Modify to pneumatic open
			U34-3 U35-3	Poppet Valve, 2-1/2 inch GO_2, GH_2 Vent and Relief Leakage not known Pneumatic close	Modification Required	Minor	(1) Modify to pneumatic open (2) Leakage probably high
100	50	GN_2, GHe, GH_2 LH_2 37°R to 580°R	U37	Same as LO_2 Ascent/Maneuver Vent and Relief (U34, U35)			Essentially same as LO_2 Vent and Relief (U34, U35) Modification to GH_2 service
100	50	GN_2, GO_2, LO_2 163°R to 580°R	U36	Same as LO_2 Ascent/Maneuver Vent and Relief (U34, U35)			Available components are larger than required. Essentially same comments as for LO_2 Ascent/Maneuver Tank Vent and Relief (U34, U35) except leakage must be greatly reduced
100	50	GH_2, GO_2, LO_2 165°R to 580°R	U39	Same as LO_2 Ascent/Maneuver Vent and Relief (U34, U35)			Available components are larger than required Essentially same comments as for LH_2 Ascent/Maneuver Tank Vent and Relief (U35, U38) except leakage must be greatly reduced.
100	50	GN_2, Ghe, GH_2 LH_2 30°R to 580°R	U40-1	Spherical Poppet, 1/4 inch Cryo GHe Valve 25 sccm Mylar Seat Solenoid Actuator	Modify	Minor	(1) Has sliding metal-metal contact (2) LH_2 qualification required (3) Appears suitable (4) Heavier than necessary (5) Modify for reduced pressure
			U40-2 U49-2	Spherical Poppet, 1/4 inch 8 sccm Metal Actuator	Reusable	None	(1) Has sliding metal-metal contact (2) Development item (3) Heavier than necessary

2

PRECEDING PAGE BLANK NOT FILMED.

CONFIDENTIAL

Table 6-2 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environm
			Gas	Liquid	M-I	M-II	
Feed System/ Ground and Flight Vent (cont.)	GH_2 Flight Vent Shutoff Valve (U41, U43)	3/4	100	Zero	100	50	GN_2, GHe, GH_2, LH_2 37°R to 580
	LO_2 Engine Isolation Shutoff Valve (U42, U46, U47)	8	(Engine valve dependent)	Zero	100	50	GN_2, GO_2, 163°R to 58
	LH_2 Engine Isolation (I43, U44, U45)	10	(Engine valve dependent)	Zero	100	50	GN_2, GHe, LH_2 37°R to 580
	LO_2 Fill and Drain Disconnect Checking Disconnect (QD 20)	8 - 10	N. A.	N. A.	100	50	GN_2, GO_2, 163°R to 5

ble 6-2 (Cont.)
ONFIDENTIAL)

te	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
ld	M-I	M-II						
	100	50	GN_2, GHe. GH_2, LH_2 37°R to 580°R	U41-1 U48-1	Globe Poppet Valve, 1-inch GO_2-GH_2 valve 1 sccm Kel F-Seal Solenoid Actuator	Modification Required	Moderate	(1) Sliding metal to metal (2) Remove Pilot poppet (3) High flow capacity (4) Relatively heavy (5) May generate contaminant
				U41-2 U48-2	Globe Poppet Valve, 3/8-inch LH_2 TCU Valve Latching Solenoid	Modification Required	Moderate	(1) Sliding metal to metal (2) Low flow capacity, should be increased
	100	50	GN_2, GO_2, LO_2 163°R to 580°R	U42-1 U46-1 U47-1	Butterfly Valve, 8-inch LO_2, LH_2 SOV	Reusable	Minor	(1) Close to requirements (2) Light weight (3) Modify actuator to cryo
	100	50	GN_2, GHe, GH_2 LH_2 37°R to 580°R	U43-1 U44-1	Visor Valve, 10-inch LO_2 Vent Valve 12000 scim Pneumatic Actuator	Modification Required	Minor	(1) Leakage high (2) Actuator should stop visor inertia when closing (3) Modify for LH_2 (4) Low pressure drop (5) Light weight (6) Remove relief pilot
				U43-2 U44-2 U45-2	Swing Poppet Valve LO_2 Vent and Relief 800 sccm 10-inch Pneumatic Actuator	Modification Required	Moderate	(1) Modify for LH_2 (2) Remove relief function (3) Upstream line enlargement required (4) Low leakage (5) Heavier than visor ball
				U43-3 U44-3 U45-3	Ball Valve, 12-inch RP1-SOV Pneumatic Actuator	Modification Required	Major	(1) Has dual seals (2) Seal change required (3) High seal wear – movable seals recommended (4) Modify actuator – cryo (5) Low pressure drop (6) High weight for application (7) Lower response than visor ball (8) High actuation torque
	100	50	GN_2, GO_2, LO_2 163°R to 580°R	QD20-1	Poppet Disconnect, 8-inch LO_2, LH_2 Disconnect 1000 sccm	Modification Required	Minor	(1) Check valve should be in air-airborne half (2) Low leakage

2

CONFIDENTIAL

PRECEDING PAGE BLANK NOT FILMED.

Table 6-2 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environment	Component Number	Available Co
			Gas	Liquid	M-I	M-II			
Feed System/ Ground and Flight Vent (cont.)	LH_2 Fill and Drain Disconnect Checking Disconnect (QD 21)	10 - 12	NA	NA	100	50	GN_2, GH3 GH_2, LH_2 37°R to 580°R	QD21-1	Poppet Disco 8 inch
	GO_2 Vent Disconnect (QD22)	6	NA	NA	100	50	GN_2, GO_2 200oR to 580°R	QD22-1	Open Disconn GO_2 Vent Dis (Two supplie 3 CCM LO_2 I
								QD22-2	Open Disconn GO_2, GH_2 350 sccm GH Checking Grc
	GH_2 Vent Disconnect (QD23)	8	NA	NA	100	50	GN_2, GHe GH_2, LH_2 100°R to 580°R	QD-23	Same as GO_2 Disconnect
	LO_2 Drop Tank Disconnect (QD24, QD25)	10	NA	NA	100	50	GN_2, GO_2, LO_2 163oR to 580°R	QD24-1	Poppet Disco 8-inch LO_2, LH_2 5000 sccm G
	LH_2 Drop Tank Disconnect QD26, QD27)	10 - 12	NA	NA	100	50	GN_2, GHe GH_2, LH_2 37°R to 580°R	QD26-1 QD27-1	Poppet Disc 8-inch LO_2, LH_2 5000 sccm G
	GO_2 Drop Tank Vent Disconnect (QD28, QD29)	5	NA	NA	100	50	GN_2, GO_2 200°R to 580°R	QD28-1 QD28-1	Open/Check connect 6- GO_2, GH_2 V Disconnect 350 sccm
								QD28-2	Open Discon 7-inch GH_2 Vent

ɩle 6-2 (Cont.)
NFIDENTIAL)

ɩe	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
c	M-I	M-II						
	100	50	GN_2, GH3 GH_2, LH_2 37°R to 580°R	QD21-1	Poppet Disconnect, 8 inch	Design Development	N. A.	(1) Adequate sizes not available (2) Check valve should be in airborne half (3) This disconnect could suffice with fill-time compromise
	100	50	GN_2, GO_2 200°R to 580°R	QD22-1	Open Disconnect, 7-inch GO_2 Vent Disconnect (Two suppliers) 3 CCM LO_2 Ext.	Reusable	None	(1) May generate contamination (2) Appears suitable (3) High flow capacity (4) Light weight
				QD22-2	Open Disconnect, 6-inch GO_2, GH_2 350 sccm GH_2 Checking Ground Half	Reusable	None	(1) May generate contamination (2) Appears suitable (3) Very light weight (4) Less flow capacity than QD22-1 but adequate (5) May generate contaminant
	100	50	GN_2, GHe GH_2, LH_2 100°R to 580°R	QD-23	Same as GO_2 Vent Disconnect			(1) Same as GO_2 Vent Disconnect (QD22)
	100	50	GN_2, GO_2, LO_2 163°R to 580°R	QD24-1	Poppet Disconnect, 8-inch LO_2, LH_2 5000 sccm Gas	Modification Required	Moderate	(1) With valves downstream, checking function must be removed (2) Larger need (3) Repeatable actuator required (4) Check valve in ground half may save as (U20 or U21) (5) Integral relief (6) Heavy for application
	100	50	GN_2, GHe GH_2, LH_2 37°R to 580°R	QD26-1 QD27-1	Poppet Disconnect, 8-inch LO_2, LH_2 5000 sccm Gas	Design Development	N. A.	(1) Sizes not available (2) Repeatable actuator needed (3) With valves downstream checking function must be removed (4) Reduce weight
	100	50	GN_2, GO_2 200°R to 580°R	QD28-1 QD28-1	Open/Checking Disconnect 6-inch GO_2, GH_2 Vent Disconnect 350 sccm	Modification Required	Moderate	(1) Has checking function which should be removed from ground-half (2) Light weight
				QD28-2	Open Disconnect, 7-inch GH_2 Vent	Modification Required	Moderate	(1) May generate contamination (2) Appears suitable (3) High flow capacity (4) Light weight

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-2 (Cont.)

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environ
			Gas	Liquid	M-I	M-II	
Feed System/ Ground and Flight Vent (cont.)	GH_2 Drop Tank Vent Disconnect (QD30, QD31)	6	NA	NA	100	50	GH_2, GH 100°R to
	TCU Expansion Valve (RG20, 21, 22)		NA	NA	100	50	GN_2, GH LH_2 30°R to 5
	TCU LH_2 Circulation Assembly M21, M22, M23		NA	NA	100	50	GN_2, GHe GH_2, LH_2 37°R to 5
	TCU LO_2 Circulation Assembly (M24, M25, M26)				100	50	GN_2, GH3 163°R to

1

able 6-2 (Cont.)

CONFIDENTIAL)

ge	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
id	M-I	M-II						
	100	50	GH_2, GHe, GN_2 100°R to 580°R	QD30 QD31	Same as GO_2 Drop Tank Vent Disconnect (QD28, QD29)			Same as GO_2 Drop Tank Vent Disconnect (QD28, QD29)
	100	50	GN_2, GHe, GH_2 LH_2 30°R to 580°R	RG20-1 RG21-1	Bellows Regulated	Reusable	None	(1) Size increase probably necessary (2) Appears suitable (3) May generate contaminant
	100	50	GN_2, GHe GH_2, LH_2 37°R to 580°R	M21 M22 M23	Axial Flow Pump Brushless DC Motor			(1) Size increase probably necessary
	100	50	GN_2, GH3, GO_2 163°R to 580°R	M24 M25 M26	Axial Flow Pump Brushless DC Motor			(1) Must be made compatible with LO_2 (2) Size increase probably necessary

2

Table 6-3

REUSABLE LAUNCH VEHICLE PRESSURIZA
REGULATOR CONTROLLED COMPONENT

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envi
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization Regulator Controlled	GHe Tank Shutoff Valve Isolates GHe Tank (U51)	1/2	~3 (Dependent upon down-stream valves)	NA	100	50	GHe 37 to 5
	GHe Fill Shutoff Valve (U52)	1/2	~25	NA	100	50	GHe 37 to 5
	LH_2 Retro Tank GHe/GH_2 Pressurization (U53)	1-1/2	~4	NA	100	50	GN_2, (LH_2 37 to 5
	GH_2 Bleed Pressurization Shutoff Valve for LH_2 Drop Tanks (U54)	3	NA	NA	100	50	GN_2, (200 to

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-35, Figure 3-11.

Table 6-3

HICLE PRESSURIZATION SUBSYSTEM –
LLED COMPONENT EXAMINATION (U)

(CONFIDENTIAL)

ange	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
iquid	M-I	M-II						
A	100	50	GHe 37 to 580°R	U51-1	Globe Poppet GO_2 SOV-1/2 inch 1500 sccm Metal-Metal Seat Detached Solenoid	Modification Required	Major	(1) Must be modified to remove one outlet (2) Leakage high (3) Solenoid is large for application
				U51-2	Piloted Poppet GHe SOV-1/2 inch Soft Seat Solenoid-Vented Poppet	Reusable	None	Susceptible to contamination (1) Appears suitable (2) Light weight (3) Bleed pilot (4) May generate contaminants
A	100	50	GHe 37 to 580°R	U52	Same as GHe Tank Shutoff Valve (U51)		-	Essentially same as GHe Tank Shutoff Valve (U51)
A	100	50	GN_2, GHe, GH_2 LH_2 37 to 580°R	U53-1	Ball Valve, 2-inch LH_2 SOV 160 sccm Soft Seat Pneumatic Actuator	Modification Required	Moderate	(1) Seat wear may be problem (2) Leakage high (3) Probably generate contaminants (4) High flow capacity
				U53-2	Poppet Valve, 2-inch LH_2 and LO_2 SOV 500 sccm Soft Seat Pneumatic Actuator	Modification Required	Moderate	(1) Leakage high (2) High flow capacity (3) Light weight
A	100	50	GN_2, GHe, GH_2 200 to 580°R	U54-1	Butterfly, 3-inch LH_2, LO_2, SOV 25 sccm Pneumatic Actuator	Modification Required	Minor	(1) Low leakage (2) Modify for higher pressure (3) High flow capacity
				U54-2	Ball valve, 2-inch LH_2 SOV 500 sccm Soft Lip Seal Pneumatic Actuator	Modification Required	Moderate	(1) Modify for higher pressure (2) Low weight (3) Low flow capacity

Figure 3-11.

CONFIDENTIAL

2

Table 6-3 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envi
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization Regulator Controlled (Cont.)	GHe Relief for Pressurant Bottle (U55)	1/2	NA	NA	100	50	GHe 37 to 5
	LO_2 Retro Tank GHe/LO_2 Pressurization (U56)	1-1/2	~3	NA	100	50	GN_2, C LH_2 37 to 5
	GHe/GO_2 Regulator Sensing Control Valve (U57)	1/4	~1	NA	100	50	GN_2, C 200 to
	GHe Pressurization Shutoff Valve for LH_2 Tanks (U58)	2	500 to 1000	NA	100	50	GN_2, C 200 to
	GHe Pressurization Shutoff Valve for LO_2 Ascent/Maneuver Tanks (U59)	3	160	NA	100	50	GN_2, C 200 to Gasiou

e 6-3 (Cont.)

NFIDENTIAL)

	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
d	M-I	M-II						
	100	50	GHe 37 to 580°R	U55-1	GHe Fill Module, 1/2-inch GHe Relief 16 sccm Soft Seats	Modification Required	Minor	(1) Reset relief pressure
				U55-2	Poppet, 1/2-inch Spherical Seat	Modification Required	Minor	(1) Reset relief pressure (2) Low leakage
	100	50	GN_2, GHe, GH_2 LH_2 37 to 580°R	U56	Same as LH_2 Retro Tank GHe/GH_2 Pressurization (U53)			Essentially same as for LH_2 Retro Tank GHe/GH_2 Pressurization (U53)
	100	50	GN_2, GHe, GN_2 200 to 580°R	U57-1	Globe Valve, 1/4-inch GHe/GH_2 Control 10 sccm 2 Position - 3 way Solenoid	Modification Required	Minor	(1) Valve heavier than required (2) Leakage high (3) Close to requirements
	100	50	GN_2, GHe, GH_2 200 to 580°R	U58-1	Ball Valve, 2-inch LH_2 SOV 160 sccm Soft Seat Pneumatic Actuator	Reusable	None	(1) Seat wear may be problem (2) Probably generate contaminants (3) Appears suitable
				U58-2	Poppet Valve, 2-inch LH_2 and LO_2 SOV 500 sccm Soft Seal Pneumatic Actuator	Reusable	None	(1) Light weight (2) Appears suitable
				U58-3	Butterfly, 3-inch LH_2, LO_2 SOV 50 sccm Pneumatic Actuator	Reusable	None	(1) Larger than required (2) Close to requirements (3) Low leakage
	100	50	GN_2, GHe, GH_2 200 to 580°R Gasious Helium	U59	Same as GHe Pressurization Shutoff Valve for LH_2 Tanks (U58)			Essentially same as GHe Pressurization Shutoff Valve for LH_2 tanks (U50) except (U50-2) leakage high

2

PRECEDING PAGE BLANK NOT FILMED.

CONFIDENTIAL

Table 6-3 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environ
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization Regulator Controlled (Cont.)	GO_2 Pressurization Shutoff Valve for LO_2 Drop Tanks (U60)	3	NA	NA	100	50	GN_2, GO 200 to 50
	GH_2 Pressurization Shutoff Valve for LH_2 Ascent/ Maneuver Tanks (U61)	3	2000	NA	100	50	GN_2, GHe 200 to 580
	GHe Pressurization Regulator (RG51)	1/2	(Dependent upon down-stream valves)	NA	100	50	GHe 37 to 580°
	GHe Pressurization Regulator (RG52)	2	(Dependent upon down-stream valves)	NA	100	50	GHe 200 to 580
	GHe Pressurization (RG53)	2	(Dependent upon down-stream valves)	NA	100	50	GHe 200 to 580

able 6-3 (Cont.)
(CONFIDENTIAL)

...e	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
...d	M-I	M-II						
	100	50	GN_2, GO_2 200 to 500°R	U60-1	Butterfly, 3-inch LH_2, LO_2 SOV 25 sccm Pneumatic Actuator	Modification Required	Minor	(1) Low leakage (2) Modify for higher pressure (3) High flow capacity
				U60-2	Ball Valve, 2-inch LH_2 SOV 160 sccm Double Soft Seats Pneumatic Actuator	Modification Required	Moderate	(1) Modify for higher pressure (2) Assure LO_2 compatibility (3) Low weight (4) Low flow capacity
				U60-3	Poppet, 2-inch LH_2-LO_2 SOV 500 sccm Soft Lip Seal Pneumatic Actuator	Modification Required	Moderate	(1) Modify for higher pressure (2) Low flow capacity (3) Light weight
	100	50	GN_2, GHe, GH_2 200 to 580°R	U61	Same as GO_2 Pressurization Shutoff Valve for LO_2 Drop Tanks			(1) Essentially same as GO_2 Pressurization Shutoff Valve for LO_2 Drop Tanks (U60) (2) No LO_2 compatibility required
	100	50	GHe 37 to 580°R	RG51-1	Piloted Poppet, 3/8-inch GHe Module Metal-Metal Seats	Modification Required	Major	(1) Must be repackaged from module (2) Soft seats to reduce leakage (3) Pilot contamination susceptible
				RG51-2	Poppet, 3/8 - 1/2 inch GHe Pressurization Regulator	Modification Required	Minor	(1) Change regulated pressure
	100	50	GHe 200 to 580°R	RG52-1	Butterfly, 2-1/4 inch GH_2, GO_2 Regulator Remote Sensing	Modification Required	Minor	(1) Modify settings (2) Integral filters may be undersize for Mission II (3) Oversize, heavy (4) Change regulator setting
	100	50	GHe 200 to 580°R	RG53	Same as RG52 GHe Pressurization Regulator (RG52)			Essentially same as GHe Pressurization Regulator (RG52)

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-3 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environme
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization Regulator Controlled (Cont.)	GO_2 Pressure Regulator for Drop Tanks (RG54)	4	NA	NA	100	50	GN_2, GO_2 200 to 580°R
	GH_2 Pressure Regulator for Drop Tanks (RG55)	4	NA	NA	100	50	GN_2, GHe, G 200 to 580°R
	GH_2 Pressurization Regulator for LH_2 Ascent/ Maneuver and Retro Tank (RG56)	2	1 (Dependent upon up stream valve)	NA	100	50	GN_2, GHe, G LH_2 37 to 580°R
	GH_2/GHe Check Valve for LH_2 Tanks (CK51, CK52)	2	<10	Zero	100	50	GN_2, GHe, G LH_2 37 to 580°R
	GO_2/GHe Check Valve for LO_2 Tanks (CK53, CK54)	2	<10	Zero	100	50	GHe GN_2, GO_2, L 163 to 580°R
	GHe Fill Disconnect (QD51)	1/2	NA	NA	100	50	GHe 37 to 500°R

ble 6-3 (Cont.)

NFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
100	50	GN_2, GO_2 200 to 580°R	RG54	Butterfly, 3-7/8 inch GO_2 Regulator	Modification Required	Minor	Modify settings
100	50	GN_2, GHe, GH_2 200 to 580°R	RG55	Same as GO_2 Pressure Regulator for Drop Tanks (RG54)			Same as GO_2 Pressure Regulator for Drop Tanks (RG54)
100	50	GN_2, GHe, GH_2 LH_2 37 to 580°R	RG56-1	Butterfly, 2-1/4 inch GH_2, GO_2 Regulator Remote Sensing	Modification Required	Minor	(1) Modify settings (2) Integral filters may be under-size for Mission II (3) Oversize
100	50	GN_2, GHe, GH_2 LH_2 37 to 580°R	CK51-1 CK52-1	Split Flapper, 2-inch GO_2 Check Valve Soft Seat	Modification Required	Minor	(1) Seal must be changed (2) Low Temp Material Substitutions (3) High flow capacity (4) Low weight (5) Replace seat
			CK51-2 CK52-2	Poppet, 1-1/2 inch LO_2 Check Valve Soft Seat	Reusable	None	(1) Susceptible to contamination (2) Heavier than split flapper (3) Somewhat low flow capacity
100	50	GHe GN_2, GO_2, LO_2 163 to 580°R	CK53 CK54	Same as GH_2/GHe Check Valve for LH_2 Tanks (CK51, CK52)			Essentially same as for GH_2, GH_2 Check Valve for LH_2 Tanks (CK51, CK52)
100	50	GHe 37 to 500°R	QD51-1	Poppet, 1/2-inch GHe Disconnect Checking 160 sccm Soft Seat	Modification Required	Minor	(1) Satisfactory leakage if valve U52 used

2

PRECEDING PAGE BLANK-NOT FILMED.

Table 6-3 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environment	Component Number	Available C
			Gas	Liquid	M-I	M-II			
Pressurization Subsystem GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization Regulator Controlled (Cont.)	LH_2 Drop Tank Pressurization Disconnect (QD52, QD53)	6	NA	NA	100	50	GN_2, GHe, GH_2 200 to 580°R	QD52-1 QD53-1 QD52-2 QD53-2	Open Disconn GO_2 Vent Dis (Two Supplie 3 ccm LO_2 Ex Ckecking/Ope 6-inch GO_2, GH_2 (ch ground halt)
	LO_2 Drop Tank Pressurization Disconnect (QD54, QD55)	6	NA	NA	100	50	GN_2, GO_2 200 to 580°R	QD54 QD55	Same as LH_2 Pressurizatio (QD52, QD53)
	GH_2 Pressure Regulator Sensing Disconnect (QD56)	1/4	NA	NA	100	50	GN_2, GHe, GH_2 200 to 580°R	QD56-1 QD56-2 QD56-3	Disconnect, 1/ GO_2 Disconne <1 sccm Disconnect, 3/ GHe Disconne Disconnect, 1/ GHe Disconne
	GO_2 Pressure Regulator Sensing Disconnect (QD57)	1/4	NA	NA	100	50	GN_2, GO_2 200 to 580°R	QD57	Same as GH_2 Regulator Sen Disconnect (QD56)
	GHe Filter (F2)	2	NA	NA	100	50	GHe	F2	
	GHe Filter (F3, F11)	2	NA	NA	100	50	200 to 580°R Gaseous Helium	F3 F11	
	GH_2 Filter (F5)	3	NA	NA	100	50	200 to 580°R Gaseous Hydrogen	F5	
	GH_2 Filter (F6)	2					Cryogenic to 500°R Gaseous Hydrogen	F6	
	GO_2 Filter (F7)	3					200 to 580°R Gaseous Oxygen	F7	

e 6-3 (Cont.)

IFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
100	50	GN_2, GHe, GH_2 200 to 580°R	QD52-1 QD53-1	Open Disconnect, 7-inch GO_2 Vent Disconnect (Two Suppliers) 3 ccm LO_2 Ext	Reusable	None	(1) May generate contamination (2) External leakage high (3) Repeatable actuator required
			QD52-2 QD53-2	Ckecking/Open Disconnect 6-inch GO_2, GH_2 (checking ground halt)	Modification Required	Minor	(1) May generate contamination (2) Checking function should be removed (3) Light weight (4) Lower flow capacity than(QD52-1)
100	50	GN_2, GO_2 200 to 580°R	QD54 QD55	Same as LH_2 Drop Tank Pressurization Disconnect (QD52, QD53)			(1) External leakage less critical than for LH_2 Tanks (2) Essentially same as LH_2 Drop Tank Pressurization Disconnect (QD52, QD53)
100	50	GN_2, GHe, GH_2 200 to 580°R	QD56-1	Disconnect, 1/4-inch GO_2 Disconnect <1 sccm			Repeatable actuator action required
			QD56-2	Disconnect, 3/8-inch GHe Disconnect			Repeatable actuator action required
			QD56-3	Disconnect, 1/4 inch GHe Disconnect			Repeatable actuator action required
100	50	GN_2, GO_2 200 to 580°R	QD57	Same as GH_2 Pressure Regulator Sensing Disconnect (QD56)			Essentially same as GH_2 Pressure Regulator Sensing Disconnect (QD56)
100	50	GHe	F2				
100	50	200 to 580°R Gaseous Helium	F3 F11				
100	50	200 to 580°R Gaseous Hydrogen	F5				
		Cryogenic to 500°R Gaseous Hydrogen	F6				
		200 to 580°R Gaseous Oxygen	F7				

CONFIDENTIAL

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-4

REUSABLE LAUNCH VEHICLE PRESSURIZA
VALVE CONTROLLED COMPONENT EX

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization Valve Controlled	GHe SOV Isolates pressurant tank (U61)	1/2	~3	NA	100	50	GHe 37 to 58
	GHe Fill SOV (U62)	1/2	~25	NA	100	50	GHe 37 to 58
	GH_2 Retro Pressurization SOV (U63)	1-1/2	~4	NA	100	50	GH_2, GH LH_2 37 to 58
	GH_2 Pressurization SOV Shutoff Valve to Drop Tank (U64)	3	NA	NA	100	50	GN_2, GH 200 to 5
	GHe Relief for Pressurant Bottle (U65)	1/2	NA	NA	100	50	GHe 37 to 58
	LO_2 Retro Pressurization SOV (U66)	2	~3	NA	100	50	GN_2, G LO_2 163 to 5
	GHe/GO_2 Regulator Sensing Control Valve (U67)	1/4	~1	NA	100	50	GN_2, G 200 to 5

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-37, Figure 3-12.

Table 6-4

LE PRESSURIZATION SUBSYSTEM --
COMPONENT EXAMINATION (U)

NFIDENTIAL)

Probable Life (flts) M-I	Probable Life (flts) M-II	Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
100	50	GHe 37 to 580°R	None	Same as GHe SOV (U51) Table 6-3			Same as U51, Table 6-3.
100	50	GHe 37 to 580°F	None	Same as GHe Fill SOV (U52) Table 6-3			Same as U52, Table 6-3.
100	50	GH_2, GHe, GH_2 LH_2 37 to 580°R	None	Same as LH_2 Retro Tank Pressurization SOV (U53) Table 6-3)			Same as U53, Table 6-3.
100	50	GN_2, GHe, GH_2 200 to 580°R	None	Same as GH_2 Bleed Pressurization SOV (U54) Table 6-3			Same as U54, Table 6-3.
100	50	GHe 37 to 580°R	None	Same as GHe Pressurant Bottle Relief (U55) Table 6-3			Same as U55, Table 6-3.
100	50	GN_2, GHe, GO_2 LO_2 163 to 580°R	None	Same as LO_2 Retro Tank GH_e Pressurization SOV Table 6-3			Same as U56, Table 6-3
100	50	GN_2, GHe, GO_2 200 to 580°R	None	Same as GHe/GO_2 Regulator Sensing Control Valve (U57) Table 6-3			Same as U57, Table 6-3

gure 3-12.

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-4 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Enviro
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization Valve Controlled (cont.)	GHe Pressurization SOV to Spacecraft LH_2 Tank (U68)	2	500 to 1000	NA	100	50	GN_2, GH 200 to 58
	GHe Pressure SOV to Spacecraft LO_2 Tank (U69)	2	160	NA	100	50	GN_2, GH 200 to 58
	GO_2 Pressurization SOV Shuts off bleed to drop tank (U70)	3	NA	NA	100	50	GN_2, GO 200 to 58
	GO_2 Bleed Flow Control Valve (U71, 72, 73, 74)	3	NA	NA	100	45	GN_2, GO 200 to 58
	GH_2 Bleed for Control Valve (U75, 76, 77, 78)	3	NA	NA	100	45	GN_2, GH 200 to 58
	GH_2 Pressurization SOV for Spacecraft (U79)	3	2000	NA	100	50	GN_2, GH 200 to 58
	GHe Pressure Regulator Pressurant Stepdown (RG61)	1/2	(Dependent upon downstream valve)		100	50	GHe 37 to 580
	GHe Pressure Regulator for Spacecraft LH_2 Tanks (RG62)	2	(Dependent upon downstream valve)		100	50	GN_2, GH 200 to 58

6-4 (Cont.)
IDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
100	50	GN_2, GHe 200 to 580°R	None	Same as LH_2 Spacecraft Tank GHe Pressurization (U58) Table 6-3			Same as U58, Table 6-3
100	50	GN_2, GHe 200 to 580°R	None	Same as LO_2 Spacecraft Tank Pressurization SOV (U59) Table 6-3			Same as U59, Table 6-3
100	50	GN_2, GO_2 200 to 580°R	None	Same as GO_2 Bleed Pressurization SOV (U60) Table 6-3			Same as U60, Table 6-3
100	45	GN_2, GO_2 200 to 580°R	None	Same as GO_2 Bleed Pressurization SOV (U60) Table 6-3			Same as U60, Table 6-3
100	45	GN_2, GHe, GH_2 200 to 580°R	None	Same as GH_2 Bleed Pressurization SOV (U54) Table 6-3			Same as U54, Table 6-3
100	50	GN_2, GHe, GH_2 200 to 580°R	None	Same as GH_2 Bleed Pressurization SOV (U61) Table 6-3			Same as U61, Table 6-3
100	50	GHe 37 to 580°R	None	Same as Stepdown GHe Pressurization Regulator (RG51) Table 6-3			Same as RG51, Table 6-3
100	50	GN_2, GHe 200 to 580°R	None	Same as LH_2 Spacecraft Pressurization Regulator (RG52) Table 6-3			Same as RG 52, Table 6-3

CONFIDENTIAL

Table 6-4 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environm
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization Valve Controlled (cont.)	GHe Regulator for Spacecraft LO_2 Tanks (RG63)	2	(Dependent upon downstream valves)		100	50	GN_2, GHe 200 to 580°
	GH_2/GHe Isolation Check Valve Prevents LH_2 From Entering Pressurization Line (CK61, 62)	2	<10	Zero	100	50	GN_2, GHe, LH_2 37 to 580°R
	GHe/GO_2 Isolation Check Valve Presents LO_2 From Entering pressurization Line (CK63, 64)	2	<10	Zero	100	50	GN_2, GHe, LO_2 163 to 580°
	GHe Fill Disconnect (QD61)	1/2	NA	NA	100	50	GHe 37 to 580°R
	GH_2 Drop Tank Disconnect (QD62, 63)	6	NA	NA	100	50	GN_2, GHe, 200 to 580°
	GO_2 Drop Tank Disconnect (QD64, 65)	6	NA	NA	100	50	GN_2, GO_2 200 to 580°
	GHe Filter (F1)				–	–	
	GHe Filter (F2)				–	–	

ble 6-4 (Cont.)
ONFIDENTIAL)

e	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
d	M-I	M-II						
	100	50	GN_2, GHe 200 to 580°F	None	Same as LO_2 Spacecraft Pressurization Regulator (RG53) Table 6-3			Same as RG53, Table 6-3
	100	50	GN_2, GHe, GH_2 LH_2 37 to 580°R	None	Same as Isolation Check Valve (CK51, 52) Table 6-3			Same as CK51, 52, Table 6-3
	100	50	GN_2, GHe, GO_2 LO_2 163 to 580°R	None	Same as Isolation Check Valve (CK53, 54) Table 6-3			Same as CK53, 54, Table 6-3
	100	50	GHe 37 to 580°R	None	Same as GHe pressurization File Disconnect QD51 Table 6-3			Same as QD51, Table 6-3
	100	50	GN_2, GHe, GH_2 200 to 580°R	None	Same as LO_2 and LH_2 Drop Tank Pressurization Line Disconnect (QD52, 53) Table 6-3)			Same as QD52, 53, Table 6-3
	100	50	GN_2, GO_2 200 to 580°R	None	Same as LO_2 and LH_2 Drop Tank Pressurization Line Disconnect (QD52, 53) Table 6-3			Same as QD52, 53, Table 6-3
	–	–						
	–	–						

2

PRECEDING PAGE BLANK NOT FILMED.

CONFIDENTIAL

Table 6-4 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environ
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem	GHe Filter (F3)				–	–	
GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization	GHe Filter (F4)				–	–	
	GHe Press Filter (F5				–	–	
Valve Controlled (cont.)	LH_2 Pressure Switch (PS61, 63)				35	15	
	LO_2 Pressure Switch (PS62)				35	15	

able 6-4 (Cont.)
CONFIDENTIAL)

age	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
quid	M-I	M-II						
	–	–						
	–	–						
	–	–						
	35	15						
	35	15						

2

Table 6-5

REUSABLE LAUNCH VEHICLE PRESSURIZATION SUBSYSTI
AUTOGENOUS COMPONENT EXAMIN
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Enviror
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem Autogenous	GH_2 Regulator Sensing Control Valve (U151)	1/4	~100	NA	100	50	GN_2, GH 100 to 58
GO_2 Bleed Prepressurization GO_2 Bleed Pressurization GH_2 Bleed Prepressurization GH_2 Bleed Pressurization Regulator Controlled	GH_2 Pressurization Shutoff Valve for LH_2 Retro Tanks (U153)	2	~500	Zero	100	50	GN_2, GH LH_2 37 to 580
	GO_2 Pressurization Shutoff Valve for GO_2 Reusable Tanks (U152)	3	~1000	Zero	100	50	GN_2, GO_2 200 to 58
	GH_2 Pressurization Shutoff Valve for LH_2 Drop Tanks (U154)	3	NA	NA	100	50	GN_2, GHe 200 to 580

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-39, Figure 3-13.

Table 6-5

ATION SUBSYSTEM – REGULATOR CONTROLLED,
PONENT EXAMINATION (U)

NFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
100	50	GN_2, GHe, GH_2 100 to 580°R	U151-1	Globe Valve, 1/4-inch GHe/GH_2 Control 10 sccm 2 Position, 3-way Solenoid	Reusable	None	Valve heavier than required
100	50	GN_2, GHe, GH_2 LH_2 37 to 580°R	U153-1	Ball Valve, 2-inch LH_2 SOV 160 sccm Soft Seat Pneumatic Actuator	Modification Required	Moderate	(1) Seat wear may be problem (2) Close to requirements
			U153-2	Poppet Valve, 2-inch LH_2 and LO_2 SOV 500 sccm Soft Seal Pneumatic Actuator	Reusable	None	(1) Leakage relatively high (2) Light weight (3) Appears suitable
			U153-3	Butterfly, 3-inch LH2, LO_2 SOV 50² sccm Pneumatic Actuator	Modification Required	Minor	(1) Larger than required (2) Leakage relatively high (3) Close to requirements
100	50	GN_2, GO_2 200 to 580°R	U152	Same as GHe Bleed Pressurization Shutoff Valve for LH_2 Drop Tanks (U154)			Essentially same as GHe Bleed Pressurization Shutoff Valve for LH_2 Drop Tanks (U154)
100	50	GN_2, GHe, GH_2 200 to 580°R	U154-1	Butterfly, 3-inch LH_2, LO_2 SOV 25 sccm Pneumatic Actuator	Modification Required	Minor	(1) Low leakage (2) Modify for higher pressure (3) High flow capacity

Figure 3-13.

2

[redacted]

Table 6-5 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem Autogenous GO_2 Bleed Prepressurization GO_2 Bleed Pressurization GH_2 Bleed Prepressurization GH_2 Bleed Pressurization Regulator Controlled (cont.)	GH_2 Bleed Pressurization Shutoff Valve for LH_2 Drop Tanks (cont.) (U154)						
	GO_2 Pressurization Shutoff Valve for LO_2 Retro Tanks (U156)	2	~500	NA	100	50	GN_2, G(163 to 5
	GO_2 Regulator Sensing Control Valve (U157)	1/4	~100	NA	100	50	GN_2, G(200 to 5
	GH_2 Pressurization Shutoff Valve for LH_2 Ascent/Maneuver Tanks (U158)	3	~1000	NA	100	50	GN_2, GI 200 to 5

6-5 (Cont.)
FIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
			U154-2	Ball Valve, 2-inch LH_2 SOV 160 sccm Double Soft Seat Pneumatic Actuator	Modification Required	Moderate	(1) Modify for higher pressure (2) Moveable seats desirable (3) Low flow capacity (4) Low weight
			U154-3	Poppet, 2-inch LH_2, LO_2 SOV 500 sccm Soft Lip Seal Pneumatic Actuator	Modification Required	Moderate	Modify for higher pressure
100	50	GN_2, GO_2, LO_2 163 to 580°R	U156	Same as GH_2 Pressurization Shutoff Valve for LH_2 Retro Tanks (U153)			Essentially same as GH_2 Pressurization Shutoff Valve for LH_2 Retro Tanks (U153)
100	50	GN_2, GO_2 200 to 580°R	U157-1	Globe Valve, 1/4-inch GHe/GH_2 Control 10 sccm 2 Position, 3-way Solenoid	Reusable	None	(1) Valve heavier than required (2) Low leakage (3) Close to requirement
100	50	GN_2, GHe, GH_2 200 to 580°R	U158-1	Butterfly, 3-inch LH_2, LO_2 SOV 25 sccm Pneumatic Actuator	Reusable	None	(1) Close to requirements (2) Low leakage for application
			U158 2	Ball Valve, 2-inch 160 sccm Double Soft Seat Pneumatic Actuator	Reusable	None	(1) Appears suitable (2) Moveable seats desirable (3) Seat wear may be problem (4) Probably generate contaminants
			U158-3	Poppet, 2-inch LH_2, LO_2 SOV 500 sccm Soft Lip Seal Pneumatic Actuator	Reusable	None	(1) Appears suitable (2) Low flow capacity (3) Light weight

2

CONFIDENTIAL

Table 6-5 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environ
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem Autogenous GO_2 Bleed Prepressurization GO_2 Bleed Pressurization GH_2 Bleed Prepressurization GH_2 Bleed Pressurization Regulator Controlled (cont.)	GO_2 Pressurization Shutoff Valve for LO_2 Ascent/Maneuver Tanks (U159)	3	~1000	NA	100	50	GN_2, GO_2, 200 to 500
	GH_2 Bleed Pressurization Shutoff Valve for LH_2 Reusable Tanks (U161)	3	~1000	NA	100	50	GN_2, GHe, 200 to 580
	GO_2 Bleed Pressurization Shutoff Valve for LO_2 Drop Tanks (U162)	3	NA	NA	100	50	GN_2, GO_2, 200 to 580
	GO_2 Pressure Regulator for LO_2 Reusable Tanks (RG153)	2	~1000	NA	100	50	GN_2, GO_2, 200 to 580
	GO_2 Pressure Regulator for LO_2 Drop Tanks (RG154)	4	NA	NA	100	50	GN_2, GO_2, 200 to 580
	GH_2 Pressure Regulator for LH_2 Drop Tanks (RG155)	4	NA	NA	100	50	GN_2, GHe, 200 to 580
	GH_2 Pressure Regulator for LH_2 Reusable Tanks (RG156)	2	~1000	NA	100	50	GH_2, GHe, 200 to 580

1

ble 6-5 (Cont.)

NFIDENTIAL)

e	Probable Life (flts)		Environment	Component Number	Available Components	Classification Reusability	Modifications Extent of	Comments
d	M-I	M-II						
	100	50	GN_2, GO_2 200 to 500°R	U159	Same as GH_2 Pressurization Shutoff Valve for LH_2 Ascent/Maneuver Tanks (U158)			Same as GH_2 Pressurization Shutoff Valve for LH_2 Ascent/Maneuver Tanks (U158)
	100	50	GN_2, GHe, GH_2 200 to 580°R	U161	Same as GH_2 Bleed Pressurization Shutoff Valve for LH_2 Reusable Tanks (U154)			Same as GH_2 Bleed Pressurization Shutoff Valve for LH_2 Reusable Tanks (U154)
	100	50	GN_2, GO_2 200 to 580°R	U162	Same as GH_2 Bleed Pressurization Shutoff Valve for LH_2 Drop Tanks (U154)			Same as GH_2 Bleed Pressurization Shutoff Valve for LH_2
	100	50	GN_2, GO_2 200 to 580°R	RG153-1	Butterfly, 2-1/4-inch GH_2, GO_2 Regulator Remote Sensing	Modification Required	Minor	(1) Modify settings (2) Integral filters may be undersize for Mission II (3) Oversize, heavy for application (4) Change regulator settings
	100	50	GN_2, GO_2 200 to 580°R	RG154-1	Butterfly, 3-7/8-inch GO_2 Regulator	Modification Required	Minor	(1) Modify settings
	100	50	GN_2, GHe, GH_2 200 to 580°R	RG155-1	Butterfly, 3-7/8-inch GO_2 Regulator	Modification Required	Minor	(1) Modify setting
	100	50	GH_2, GHe, GH_2 200 to 580°R	RE156-1	Butterfly, 2-1/4-inch GH_2, GO_2 Regulator Remote Sensing	Modification Required	Minor	(1) Modify settings (2) Integral filters may be undersize for Mission II (3) Oversize, heavy

2

Table 6-5 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environme
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem Autogenous	GH_2 Check Valves for LH_2 Tanks (CK151, CK152)	2	~100	Zero	100	50	GN_2, GHe, G LH_2 37 to 580°R
GO_2 Bleed Prepressurization GO_2 Bleed Pressurization GH_2 Bleed Prepressurization GH_2 Bleed Pressurization	GO_2 Check Valves for LO_2 Tanks (CK153, CK154)	2	~100	Zero	100	50	GN_2, GO_2, L 163 to 580°R
Regulator Controlled (cont.)	GH_2 Pressurization LH_2 Drop Tank Disconnects (QD152, QD153)	6	NA	NA	100	50	GN_2, GHe, G 200 to 580°R
	GO_2 Pressurization LO_2 Drop Tank Disconnects (QD154, QD155)		NA	NA	100	50	GN_2, GO_2 200 to 580°R
	GH_2 Pressure Regulator Sensing Disconnect (QD156)		1/4	NA	100	50	GN_2, GHe, G 200 to 580°R

ble 6-5 (Cont.)

ONFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
100	50	GN_2, GHe, GH_2 LH_2 37 to 580°R	CK151-1 CK152-1	Split Flapper, 2-inch GO_2 Check Valve Soft Seat	Modification Required	Minor	(1) Seat must be changed (2) Low temp. material substitutions (3) High flow capacity (4) Low weight (5) Replace seat
			CK151-2 CK152-2	Poppet, 1-1/2-inch LO_2 Check Valve Soft Seat	Reusable	None	(1) Susceptible to contamination (2) Heavier than split flapper (3) Somewhat low flow capacity
100	50	GN_2, GO_2, LO_2 163 to 580°R	CK153 CK154	Same as GH_2 Check Valves for LO_2 Tanks (CK151, CK152)			Essentially same as GH_2 Check Valves for LH_2 Tanks (CK153, CK154)
100	50	GN_2, GHe, GH_2 200 to 580°R	QD152-1 QD153-1	Open Disconnect, 7-inch GO_2 Vent Disconnect (Two Suppliers) 3 ccm LO_2 Ext.	Reusable	None	(1) May generate contamination (2) External leakage high (3) Repeatable actuator needed
			QD152-2 QD153-2	Checking/Open Disconnect, 6-inch GO_2/GH_2 (Checking Ground Half)	Modification Required	Minor	(1) May generate contamination (2) Checking function should be removed (3) Repeatable actuator needed (4) Low weight
100	50	GN_2, GO_2 200 to 580°R	QD154 QD155	Same as GH_2 Pressurization LH_2 Drop Tank Disconnects (QD152, QD153)			(1) External leakage less critical than for LH_2 tanks (2) Essentially same as GH_2 Pressurization for LH_2 Drop Tank Disconnects (QD152, QD153)
100	50	GN_2, GHe, GH_2 200 to 580°R	QD156-1	Disconnect, 1/4-inch GO_2 Disconnect <1 sccm			Repeatable actuator action required
			QD156-2	Disconnect, 3/8-inch GHe Disconnect			Repeatable actuator action required
			QD156-3	Disconnect, 1/4-inch GHe Disconnect			Repeatable actuator action required

CONFIDENTIAL

2

Table 6-5 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environ
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem Autogenous	GO_2 Pressure Regulator Sensing Disconnect (QD157)	1/4	NA	NA	100	50	GN_2, GO_2 200 to 580
GO_2 Bleed Prepressurization GO_2 Bleed Pressurization	GO_2 Filter (F10)	3	NA	NA	100	50	GN_2, GO_2 200 to 580
GH_2 Bleed Prepressurization GH_2 Pressurization	GO_2 Filter (F11)	2	NA	NA	100	50	GN_2, GO_2 200 to 580
Regulator Controlled (cont.)	GH_2 Filter (F12)	3	NA	NA	100	50	GN_2, GHe 200 to 580
	GH_2 Filter (F13)	2-1/2	NA	NA	100	50	GN_2, GHe 200 to 580

1

ble 6-5 (Cont.)
ONFIDENTIAL)

e	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
d	M-I	M-II						
	100	50	GN_2, GO_2 200 to 580°R	QD157	Same as GH_2 Pressure Regulator, Sensing Disconnect (QD156)			Repeatable actuator action required
	100	50	GN_2, GO_2 200 to 580°R	F10				
	100	50	GN_2, GO_2 200 to 580°R	F11				
	100	50	GN_2, GHe, GH_2 200 to 580°R	F12				
	100	50	GN_2, GHe, GH_2 200 to 580°R	F13				

2

Table 6-6

REUSABLE LAUNCH VEHICLE PRESSURIZATION SUBSYSTE
AUTOGENOUS COMPONENT EXAMINAT

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environ
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem Autogenous GO_2 Bleed Prepressurization GO_2 Pressurization GH_2 Bleed Prepressurization GH_2 Bleed Pressurization Valve Controlled	GH_2 Pressurization SOV Shuts off bleed to hydrogen retro tank (U163)	2	~500	Zero	100	50	GN_2, GH LH_2 37 to 580
	GH_2 Pressurization SOV Shuts off bleed to LH_2 drop tanks (U164)	3	NA	NA	100	50	GN_2, GH 200 to 58
	GH_2 Pressurization SOV Shuts off bleed to spacecraft LH_2 tanks (U165)	3	~1000	NA	100	50	GN_2, GH 200 to 58
	GO_2 Pressurization SOV Shuts off bleed GO_2 to LO_2 retro tank (U166)	2	~500	NA	100	50	GN_2, GO 163 to 58
	GO_2 Pressurization SOV Shuts off bleed GO_2 to spacecraft LO_2 tanks (U169)	3	~1000	Zero	100	50	GN_2, GO 200 to 58
	GO_2 Pressurization SOV Shuts off bleed to LO_2 drop tanks (U170)	3	NA	NA	100	50	GN_2, GO 200 to 58

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-41, Figure 3-14.

1

Table 6-6

RIZATION SUBSYSTEM – VALVE CONTROLLED,
PONENT EXAMINATION (U)

NFIDENTIAL)

ge	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
ld	M-I	M-II						
o	100	50	GN_2, GHe, GH_2 LH_2 37 to 580°R	None	Same as Spacecraft LH_2 Tank GHe Pressurization SOV (U58) Table 6-3			(1) Same as U58, Table 6-3 (2) Appears suitable
	100	50	GN_2, GHe, GH_2 200 to 580°R	None	Same as GH_2 Bleed Pressurization SOV (U54) Table 6-3			Same as U54, Table 6-3
	100	50	GN_2, GHe, GH_2 200 to 580°R	None	Same as GH_2 Bleed Pressurization SOV (U54) Table 6-3			Same as U54, Table 6-3
	100	50	GN_2, GO_2, LO_2 163 to 580°R	None	Same as Spacecraft LH_2 Tank GHe Pressurization SOV (U58) Table 6-3			(1) Same as U58, Table 6-3 (2) Appears suitable
	100	50	GN_2, GO_2 200 to 580°R	None	Same as GH_2 Bleed Pressurization SOV (U54) Table 6-3			Same as U54, Table 6-3
	100	50	GN_2, GO_2 200 to 580°R	None	Same as Spacecraft LH_2 GHe Pressurization SOV			(1) Same as U58, Table 6-3 (2) Appears suitable

igure 3-14.

Table 6-6 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-I	M-II	
Pressurization Subsystem **Autogenous** **GO_2 Bleed Prepressurization** **GO_2 Pressurization** **GH_2 Bleed Prepressurization** **GH_2 Bleed Pressurization** **Valve Controlled** **(cont.)**	GO_2 bleed flow control valve (U171, 172, 173, 174)	3	NA	NA	100	35	GN_2, G 200 to
	GH_2 bleed flow control valve (U175, 176, 177, 178)	5	NA	NA	100	35	GN_2, G 200 to
	GH_2 Isolation Check Valve Prevents LH_2 from entering bleed lines (CK161, 162)	2	~100	Zero	100	50	GN_2, G LH_2 37 to 5
	GO_2 Isolation Check Valve Prevents LO_2 from entering bleed line (CK163, 164)	2	~100	Zero	100	50	GN_2, G 163 to 5
	GH_2 Drop Tank Disconnect (QD162, 163)	6	NA	NA	100	50	GH_2, G 200 to 5
	GO_2 Drop Tank Disconnect (QD164, 165)	6	NA	NA	100	50	GN_2, G 200 to 5
	GH_2 Filter				–	–	
	GO_2 Filter				–	–	
	GH_2 Pressure Switch				35	10	
	GO_2 Pressure Switch				50	20	

1

PRECEDING PAGE BLANK-NOT FILMED.

(Cont.)

NTIAL)

...able (flts) M-II	Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
35	GN_2, GO_2 200 to 580°R	None	Same as Spacecraft LH_2 GHe pressurization SOV (U58) Table 6-3			(1) Same as U58, Table 6-3 (2) Appears suitable
35	GN_2, GHe, GH_2 200 to 580°R	None	Same as GH_2 Bleed Pressurization SOV (U54) Table 6-3			Same as U54, Table 6-3
50	GN_2, GHe, GH_2 LH_2 37 to 580°R	None	Same as Isolation Check Valve (CK51, 52) Table 6-3			(1) Same as CK51, 52, Table 6-3 (2) Appears suitable
50	GN_2, GO_2, LO_2 163 to 580°R	None	Same as Isolation Check Valve (CK51, 52) Table 6-3			(1) Same as CK51, 52, Table 6-3 (2) Appears suitable
50	GH_2, GHe, GH_2 200 to 580°R	None	Same as LO_2, LH_2 Drop Tank Pressurization Line Disconnect (QD52, 53) Table 6-3			(1) Same as QD52, 53, Table 6-3 (2) Appears suitable
50	GN_2, GO_2 200 to 580°R	None	Same as LO_2 and LH_2 Drop Tank Pressurization Line Disconnect (QD52, 53) Table 6-3)			(1) Same as QD52, 53, Table 6-3 (2) Appears suitable
–						
–						
10						
20						

2

CONFIDENTIAL

Table 6-7

REUSABLE LAUNCH VEHICLE PRESSU
COMPONENT EXAMINATI

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-I	M-II	
Pressurant Heating for Subsystems Utilizing: GHe Prepressurization; GHe LO_2 Pressurization; GH_2 LH_2 Pressurization (Independent of Regulator or Valve Modulated Type of Control)	GHe Fill Shutoff Valve (U101)	1/8	<10	NA	100	50	GHe 400 to 58
	GHe Relief Valve (U102)	1/8 – 1/4	NA	NA	100	50	GHe 400 to 58
	GHe Pressurant Shutoff Valve (U103)	1/8	~1	NA	100	50	GHe 400 to 58
	N_2O_4 Relief Valve (U104)	1/8	<1	Zero	100	50	N_2O_4, G 400 to 5
	N_2O_4 Fill Shutoff Valve (U105)	1/8	<1	Zero	100	50	N_2O_4, G 400 to 5

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-35, Figure 3-11.

1

Table 6-7

I VEHICLE PRESSURANT HEATING
ONENT EXAMINATION (U)

CONFIDENTIAL)

age	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
uid	M-I	M-II						
A	100	50	GHe 400 to 580°R	U101-1	Poppet, 1/8-inch GHe SOV O-Ring Seat Coaxial Solenoid	Reusable	None	(1) Appears satisfactory (2) Low leakage (3) Low weight
				U101-2	Poppet, 1/8-inch GHe SOV Soft Seat Coaxial Solenoid	Reusable	None	(1) Possibly some seat erosion (2) Low leakage
A	100	50	GHe 400 to 580°R	U102-1	Relief Valve, 1/4-inch GO_2 Relief Pinch Valve	Reusable	None	(1) Appears satisfactory (2) Somewhat heavy
A	100	50	GHe 400 to 580°R	U103-1	Poppet, 1/8-inch GHe SOV O-Ring Seat Coaxial Solenoid	Reusable	None	(1) Appears satisfactory (2) Low leakage (3) Low weight
				U103-2	Poppet, 1/8-inch GHe SOV Soft Seat Coaxial Solenoid	Reusable	None	(1) Possibly some seat erosion (2) Low leakage
ro	100	50	N_2O_4, GN_2 400 to 580°R	U104-1	Poppet, 3/8-inch Soft Seat Integral Filter	Modification Required	Minor	(1) Reset cracking pressure
				U104-2	Poppet, 1/4-inch Soft Seat Integral Filter and Burst Disc	Modification Required	Minor	(1) Reset cracking pressure
ro	100	50	N_2O_4, GN_2 400 to 580°	U105-1	Poppet, 1/4 inch N_2O_4, MMH, GHe SOV 1/3 sccm Spherical Metal-Metal Seat Latching Solenoid	Reusable	None	(1) May be vibration sensitive (2) High flow capacity (3) Heavier than necessary

Figure 3-11.

2

Table 6-7 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environm
			Gas	Liquid	M-I	M-II	
Pressurant Heating for Subsystems Utilizing: GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization (Independent of Regulator or Valve Modulated Type of Control) (Cont.)	N_2O_4 Fill Shutoff Valve (U105) (Cont.)						
	MMH (or 50-50) Fill Shutoff Valve (U106)	1/8	<1	Zero	100	50	MMH, GN_2 400 to 580
	N_2O_4 Tank Shutoff Valve (U107)	1/8	<1	Zero	100	50	N_2O_4, GN 400 to 580°
	MMH (or 50-50) Tank Shutoff Valve (U108)	1/8	<1	Zero	100	50	MMH, GN 400 to 580°
	MMH (or 50-50) Relief Valve (U109)	1/8	<1	Zero	100	50	MMH, GN 400 to 580°

ble 6-7 (Cont.)
ONFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
			U105-2	Poppet, 1/4-inch GHe SOV O-Ring Seat Coaxial Solenoid	Reusable	None	(1) May generate contamination (2) Low leakage (3) Low weight
			U105-3	Poppet N_2O_4 SOV 1/10 sccm			
100	50	MMH, GN_2 400 to 580°R	U106-1	Poppet, 1/4-inch N_2O_4, MMH, GHe SOV 1/3 sccm Spherical Metal-Metal Seat Latching Solenoid	Reusable	None	(1) May be vibration sensitive (2) High flow capacity (3) Heavier than necessary
			U106-2	Poppet, 1/4-inch GHe SOV O-Ring Seat Coaxial Solenoid	Reusable	None	(1) May generate contamination (2) Low weight (3) Low leakage
			U106-3	Poppet N_2O_4 SOV 1/10 sccm			
			U106-4	Poppet, 1/3-inch MMH Valve 1/10 sccm	Reusable	None	(1) Heavy for application (2) High leakage
100	50	N_2O_4, GN_2 400 to 580°R	U107	Same as N_2O_4 Fill Shutoff Valve (U105)			Essentially same as N_2O_4 Fill Shutoff Valve (U105)
100	50	MMH, GN_2 400 to 580°R	U108	Same as MMH (or 50-50) Tank Shutoff Valve			Essentially same as MMH (or 50-50) Tank Shutoff Valve
100	50	MMH, GN_2 400 to 580°R	U109	Same as N_2O_4 Relief Valve (U104)			Essentially same as N_2O_4 Relief Valve (U104)

2

CONFIDENTIAL

Table 6-7 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environ
			Gas	Liquid	M-I	M-II	
Pressurant Heating for Subsystems Utilizing: GHe Prepressurization GHe LO_2 Pressurization GH_2 LH_2 Pressurization (Independent of Regulator or Valve Modulated Type of Control) (Cont.)	N_2O_4 Tank Fill Vent Valve (U110)	1/8	<1	Zero	100	50	N_2O_4, GN 400 to 580
	MMH (or 50-50) Tank Fill Vent Valve (U111)	1/8	<1	Zero	100	50	MMH, GN 400 to 580
	GHe Pressure Regulator (RG101)	1/8	(Dependent upon valves)	NA	100	50	GHe 400 to 580
	N_2O_4 Check Valves (CK101, CK102)	1/8 – 1/4	Neg	Zero	100	50	N_2O_4, GN 400 to 580

1

le 6-7 (Cont.)

NFIDENTIAL)

Probable Life (fits) M-I	Probable Life (fits) M-II	Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Components
100	50	N_2O_4, GN_2 400 to 580°R	U110-1	Poppet, 1/8-inch N_2O_4, MMH 1/6 sccm Coaxial Solenoid	Reusable	None	(1) Appears satisfactory (2) Light weight (3) Low leakage
			U110-2	Poppet, 1/8-inch N_2O_4 MMH 1/100 sccm	Reusable	None	
			U110-3	Poppet, 1/8-inch N_2O_4 MMH	Reusable	None	
100	50	MMH, GN_2 400 to 580°R	U111	Same as N_2O_4 Tank Fill Vent Valve (U110)			Same as N_2O_4 Tank Fill Vent Valve (U110)
100	50	GHe 400 to 580°R	RG101-1	Poppet, 1/4-inch GHe Regulator (Fume compatible) 2 sccm	Reusable	None	
			RG101-2	Poppet, 1/4-inch GHe Regulator (Others available)	Modification Required	Minor	
100	50	N_2O_4, GN_2 400 to 580°R	CK101-1 CK102-1	Poppet, 1/8-inch N_2O_4, MMH 1 sccm Soft Seat	Reusable	None	(1) May generate contamination (2) High flow capacity
			CK101-2 CK102-2	Poppet, 1/4-inch N_2O_4, MMH Soft Seat	Reusable	None	(1) May generate contamination (2) High flow capacity
			CK101-3 CK102-3	Poppet, 1/4-inch 4-Series/Parallel GHe Check Valve Neg Leakage	Reusable	None	(1) Very low leakage (2) High flow capacity (3) Integral filters (4) Light weight
			CK101-4 CK102-4	Poppet, 1/4-inch N_2O_4, MMH 16 sccm	Reusable	None	

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-7 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environ
			Gas	Liquid	M-I	M-II	
Pressurant Heating for Subsystems Utilizing: GHe Prepressurization, GHe LO_2 Pressurization, GH_2 LH_2 Pressurization (Independent of Regulator or Valve Modulated Type of Control) (Cont.)	MMH (or 50-50) Check Valves) (CK103, CK104)	1/8 – 1/4	Neg	Zero	100	50	MMH, GN 400 to 580
	GHe Fill Disconnect (D101)	1/8	NA	NA	100	50	GHe 400 to 580
	N_2O_4 Fill Disconnect (D102)	1/8	NA	NA	100	50	N_2O_4, GN 400 to 580
	MMH (or 50-50) Fill Disconnect (D103)	1/8	NA	NA	100	50	MMH, GN 400 to 580
	N_2O_4 Fill Vent Disconnect (D104)	1/8	NA	NA	100	50	N_2O_4, GN 400 to 580
	MMH (or 50-50) Fill Vent Disconnect (D105)	1/8	NA	NA	100	50	MMH, GN 400 to 580
	GHe Filter (F101)	1/8	NA	NA	100	50	GHe 400 to 580
	Burner Unit (BU101)		NA	NA	100	50	Hot Side t 2200°F N_2O_4/MM Combusti Gaseous H

ble 6-7 (Cont.)
ONFIDENTIAL)

e	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
d	M-I	M-II						
	100	50	MMH, GN_2 400 to 580°R	CK103 CK104	Same as N_2O_4 Check Valves (CK101, CK102)			Same as N_2O_4 Check Valves (CK101, CK102)
	100	50	GHe 400 to 580°R	D101-1	Disconnect 1/4 inch GHe Fill 100 sccm	Reusable	None	(1) Must be used with SOV
	100	50	N_2O_4, GN_2 400 to 580°R	D102-1	Disconnect 3/8 inch N_2O_4, MMH Fill Disconnect Neg Leakage	Reusable	None	
	100	50	MMH, GN2 400 to 580°R	D103	Same as N_2O_4 Fill Disconnect (D102)			Same as N_2O_4 Fill Disconnect (D102)
	100	50	N_2O_4, GN_2 400 to 580°R	D104	Same as N_2O_4 Fill Disconnect (D102)			Must be fume compatible.
	100	50	MMH, GN_2 400 to 580°R	D105	Same as N_2O_4 Fill Disconnect (D102)			Must be fume compatible.
	100	50	GHe 400 to 580°R	F101				
	100	50	Hot Side to 2200°F N_2O_4/MMH Combustion Gaseous Helium	BU101				Burner unit must be developed.

2

Table 6-8

REUSABLE LAUNCH VEHICLE ATTITUDE CC
COMPONENT EXAMINATION

(CONFIDENTIAL)

Subsystem	Components	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-I	M-II	
Attitude Control Subsystem N_2O_4/MMH Propellants Thrust-300 lb per nozzle	GHe Pressurant Shutoff Valve (U201, U202, U203)	1/8	< 1	NA	100	50	GHe 400 to
	MMH Tank Relief Valve (U205)	1/8	< 1	NA	100	50	MMH, 400 to
	N_2O_4 Tank Relief Valve (U206)	1/8	< 1	NA	100	50	N_2O_4, 400 to
	N_2O_4 Tank Fill Vent Valve (U207)	1/8	< 1	Zero	100	50	N_2O_4, 400 to
	MMH Tank Fill Vent Valve (U208)	1/8	< 1	Zero	100	50	MMH, 400 to

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-43, Figure 3-15.

1

Table 6-8

LE ATTITUDE CONTROL SUBSYSTEM
T EXAMINATION (U)

NFIDENTIAL)

Probable Life (flts) M-I	Probable Life (flts) M-II	Environment	Component Numbers	Available Components	Reusability Classification	Extent of Modifications	Comments
100	50	GHe 400 to 580°R	U201-1 U202-1 U203-1	Poppet, 1/8 inch GHe SOV O-Ring Seat Coaxial Solenoid	Reusable	None	(1) Appears satisfactory (2) Low leakage (3) Low weight
			U201-2 U202-2 U203-2	Poppet, 1/8 inch GHe SOV Soft Seat Coaxial Solenoid	Reusable	None	(1) Possibly some seat erosion (2) Low leakage
100	50	MMH, GN_2 400 to 580°R	U205-1	Poppet, 3/8 inch Soft Seat Integral Filter	Modification Required	Minor	(1) Reset cracking pressure
			U205-2	Poppet, 1/4 inch Soft Seat Integral Filter and Burst Disc	Modification Required	Minor	(1) Reset cracking pressure
100	50	N_2O_4, GN_2 400 to 580°R	U206	Same as MMH Tank Relief Valve (U205)			Essentially same as MMH Tank Relief Valve (U205)
100	50	N_2O_4, GN_2 400 to 580°R	U207-1	Poppet, 1/8 inch N_2O_4, MMH 1/6 sccm Coaxial Solenoid	Reusable	None	(1) Appears satisfactory (2) Low leakage (3) Low weight
			U207-2	Poppet, 1/8 inch N_2O_4, MMH 1/100 sccm			
			U207-3	Poppet, 1/8 inch N_2O_4, MMH			
100	50	MMH, GN_2 400 to 580°R	U208	Same as N_2O_4 Tank Fill Vent Valve (U207)			Same as N_2O_4 Tank Fill Vent Valve (U207)

ure 3-15.

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-8 (Cont.)
(CONFIDENTIAL)

Subsystem	Components	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envi
			Gas	Liquid	M-I	M-II	
Attitude Control Subsystem **N_2O_4/MMH Propellants** **Thrust-300 lb per nozzle (Cont.)**	MMH Tank Shutoff Valve (U209, U211)	1/2	1	Zero	100	50	MMI 400
	N_2O_4 Tank Shutoff Valve (U210, U212)	1/2	1	Zero	100	50	N_2O_4 400 t
	N_2O_4 Fill and Drain Shutoff Valve (U213)	1/2	1	Zero	100	50	N_2O_4 400 t
	MMH Fill and Drain Shutoff Valve (U214)	1/2	1	Zero	100	50	MMH 400 t
	MMH Cluster Shutoff Valve (U215, U221, U222)	1/4	1	Zero	100	50	MMH 400 t
	N_2O_4 Cluster Shutoff Valve (U218, U223, U224)	1/4	1	Zero	100	50	N_2O_4 400 t
	GHe Pressurization Regulator (RG 200)	1/8	1	NA	100	50	GHe 400 t

1

ble 6-8 (Cont.)

ONFIDENTIAL)

ge	Probable Life (flts)		Environment	Component Numbers	Available Components	Reusability Classification	Extent of Modifications	Comments
uid	M-I	M-II						
ro	100	50	MMH, GN_2 400 to 580°R	U209-1 U211-1	Piloted Poppet, 1/2 inch LO_2 SOV Soft Seat Solenoid	Modification Required	Minor	(1) Solenoid latching must be added (2) Pilot subject to contamination (3) High flow capacity (4) Light weight
				U209-2 U211-2	Piloted Poppet, 1/2 inch N_2O_4, MMH Metal-Metal Seat 1/3 sccm Latching Solenoid	Reusable	None	May be sensitive to severe vibration (bellows)
				U209-3 U211-3	Gate valve, 1/2 inch Solenoid	Modification Required	Minor	Seat may generate contamination
				U209-4 U211-4	Poppet, 5/8 inch N_2O_4, MMH Soft Seat 1/6 sccm	Reusable	None	
ro	100	50	N_2O_4, GN_2 400 to 580°R	U210 U212	Same as MMH Tank Shutoff Valve (U209)			Same as MMH tank shutoff valve (U209)
ro	100	50	N_2O_4, GN_2 400 to 580°R	U213	Same as N_2O_4 Tank Shutoff Valve (U210, U212)			Same as N_2O_4 tank shutoff valve (U210, U212)
ro	100	50	MMH, GN_2 400 to 580°R	U214	Same as MMH Tank shutoff valve (U209, U211)			Same as MMH tank shutoff valve (U209, U211)
ro	100	50	MMH, GN_2 400 to 580°R	U215 U221 U222	Piloted Poppet, 1/2 inch N_2O_4, MMH Metal-Metal Seat	Reusable	None	(1) May be sensitive to severe vibration
ro	100	50	N_2O_4, GN_2 400 to 580°R		U215, U221, U222			
	100	50	GHe 400 to 580°R	RG200-1	Poppet, 1/4 inch GHe Regulator (Fume Compatible) 2 sccm	Reusable	None	
				RG200-2	Poppet, 1/4 inch GHe Regulator Others Available	Reusable	None	

CONFIDENTIAL

Table 6-8 (Cont.)
(CONFIDENTIAL)

Subsystem	Components	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-I	M-II	
Attitude Control Subsystem N_2O_4/MMH Propellants Thrust-300 lb per nozzle (Cont.)	GHe/MMH Quad Check Valves (CK201)	1/8	Net	Zero	100	50	GHe/ 400 t
	GHe/N_2O_4 Qual Check Valves (CK202)	1/8	Neg	Zero	100	50	GHe/ 400 t
	GHe Fill Disconnect (D200)	1/8	NA	NA	100	50	GHe 400 t
	N_2O_4 Vent Disconnect (D201)	1/8	NA	NA	100	50	N_2O_4 400 t
	MMH Vent Disconnect (D202)	1/8	NA	NA	100	50	MMH 400 t
	N_2O_4 Fill Disconnect (D203)	1/2	NA	NA	100	50	N_2O_4 400 t
	MMH Fill Disconnect (D204)	1/2	NA	NA	100	50	MMH 400 t

e 6-8 (Cont.)
(FIDENTIAL)

Probable Life (flts)		Environment	Component Numbers	Available Components	Reusability Classification	Extent of Modifications	Comments
M-I	M-II						
100	50	GHe/MMH 400 to 580°R	CK201-1	Poppet, 1/8 inch N_2O_4, MMH 1 sccm Soft Seat	Reusable	None	(1) May generate contamination
			CK201-2	Poppet, 1/4 inch N_2O_4, MMH Soft Seat	Reusable	None	(1) May generate contamination (2) High flow capacity
			CK201-3	Poppet Conical, 1/4 inch 4-Series/Parallel GHe Check Valve Neg Leakage	Reusable	None	(1) Very low leakage (2) High flow capacity (3) Integral filters (4) Light weight
			CK201-4	Poppet, 1/4 inch N_2O_4 MMH 16 sccm	Reusable	None	
100	50	GHe/N_2O_4 400 to 580°R	CK202	Same as GHe/MMH Quad Check Valves (CK201)			Same as GHe/MMH Qual Check Valves (CK201)
100	50	GHe 400 to 580°R	D200-1	Disconnect, 1/4 inch GHe Fill 100 sccm	Reusable	None	Must be used with SOV
100	50	N_2O_4, GN 400 to 580°R	D201-1	Disconnect, 3/8 inch N_2O_4, MMH Fill Disconnect Neg Leakage	Reusable	None	
100	50	MMH, GN_2 400 to 580°R	D202-1	Same as N_2O_4 Vent Disconnect (D201)			Same as N_2O_4 Vent Disconnect (D201)
100	50	N_2O_4, GN_2 400 to 580°R	D203-1	1 inch	Reusable	None	
100	50	MMH, GN_2 400 to 580°R	D204-1	Same as N_2O_4 Fill Disconnect (D203)			Same as N_2O_4 Fill Disconnect (D203)

2

CONFIDENTIAL

Table 6-8 (Cont.)

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Enviro
			Gas	Liquid	M-I	M-II	
Attitude Control Subsystem N_2O_4/MMH Propellants Thrust-300 lb per nozzle (Cont.)	GHe Filter (F201)	1/8	NA	NA	100	50	GHe 400 to 5
	Burst Disc - N_2O_4 (BD201)	1/8	NA	NA	100	50	N_2O_4, G 400 to 5
	Burst Disc - MMH (BD202)	1/8	NA	NA	100	50	MMH, G 400 to 5
	Pressure Transducer (PT201, PT202)		NA	NA	100	50	GHe 400 to 5
	Thrusters	300 lb		Zero	85	100	200 to 5

1

ble 6-8 (Cont.)

NFIDENTIAL)

e	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
d	M-I	M-II						
	100	50	GHe 400 to 580°R	F201				
	100	50	N_2O_4, GN_2 400 to 580°R	BD201				
	100	50	MMH, GN_2 400 to 580°R	BD202				
	100	50	GHe 400 to 580°R	PT201 PT202				
5	85	100	200 to 580°R	T-1	300 lb N_2O_4/MMH I_{sp}-Steady 289			(1) Design only (2) Engine must be developed
				T-2	316 lb N_2O_4/MMH Ablative I_{sp} Steady 292			(1) Only 1000 seconds demonstrated (2) Development required
				T-3	300 lb N_2O_4/MMH I_{sp} Steady 292 Min-Pulse Bit 2-6			(1) Cycle life not demonstrated (2) Test engine only (3) Development required

2

Table 6-9

SUMMARY OF COMPONENT AVAILABILITY FOR THE REUSABLE LAUNCH VEHICLE (U)

(CONFIDENTIAL)

Component Class	General Conclusions
Propellant Feedline Valves	Suitable components are available with modifications. Gas leakages tend to be higher than desired. Actuators should be modified for cryogenic temperatures.
Vent and Relief Valves	Suitable components are available with modifications. Gas leakages tend to be higher than desired. Actuators should be modified for cryogenic temperatures.
Thermal Conditioning Units	Units with more capacity are required than those currently under development.
Liquid Line Quick Disconnects	If propellant crossfeed from drop tanks is used, larger disconnects are required. The units must have more predictable response. (Alternate combination of valves and line separators may be used.)
Vent Disconnects	If vents are connected from the Drop Tanks to the Reusable Launch Vehicle, these must have more predictable responses than existing disconnects. Components of compatible sizes are available.
Fill and Drain Disconnects	Larger diameters are desirable.
Pressurization Disconnects	If the Drop Tanks are to be pressurized from the Spacecraft, more predictable responses are necessary.
Pressurization Valves	If helium pressurization is used, valve leakages tend to be too high. Suitable sizes are available.
Pressurization Regulators	Suitable components available. Capacities of integral filters may have to be increased.
Pressure Switches	Lifetime extensions are required.
Pressure Transducers	Lifetime extensions are required.
Propellant Utilization	Vehicles would benefit from improved accuracies.
Liquid Level Devices	Lifetime extensions are needed.
Check Valves	Lifetime extensions are needed. This is particularily required for attitude control subsystems.
Attitude Control System Thrusters	Lifetime extensions are needed. Also, Oxygen/Hydrogen Attitude Control Thrusters are required.

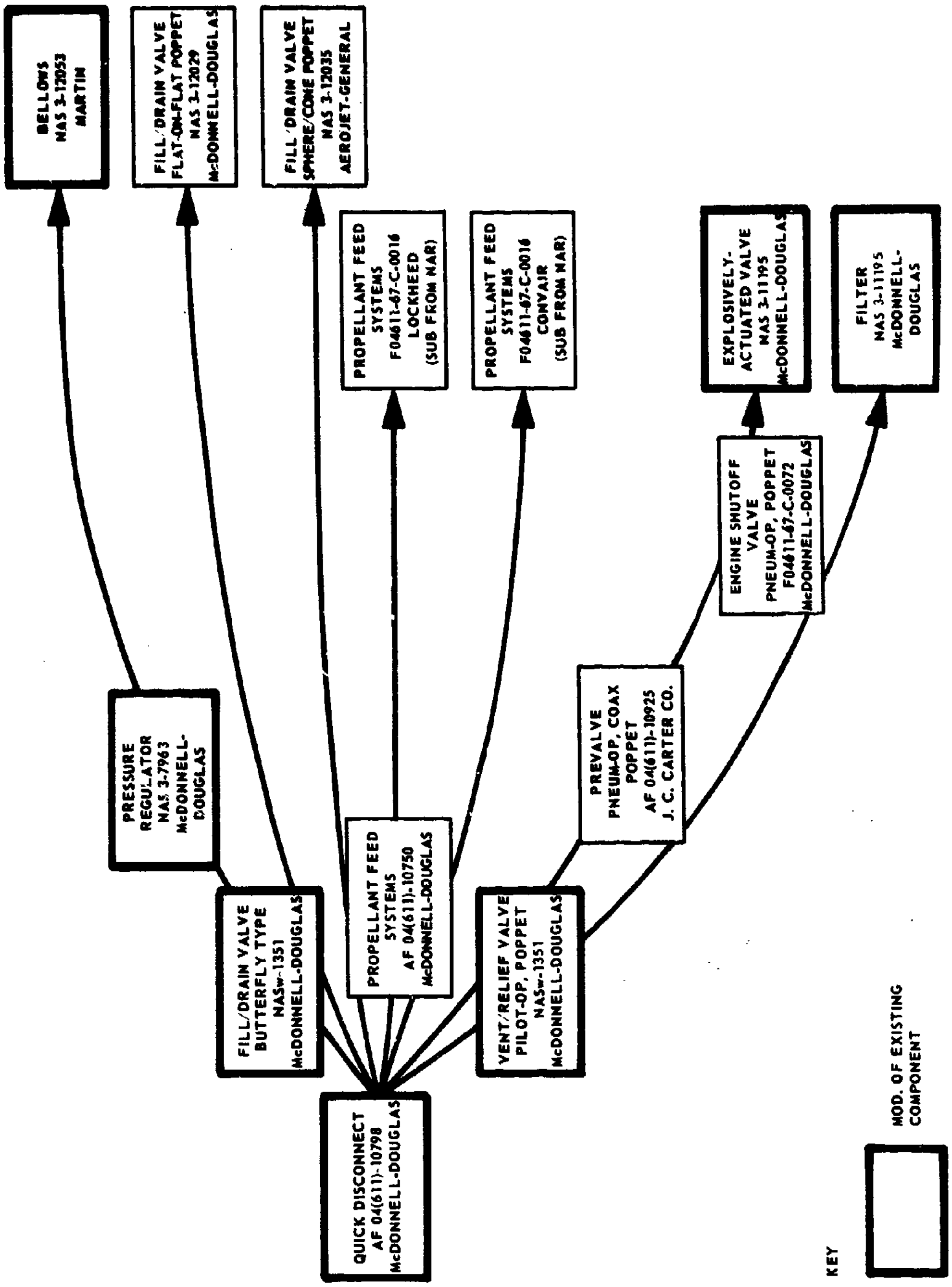


Figure 6-1 Previous LF_2 Subsystem and Component Developments (U)

CONFIDENTIAL

Table 6-10

CRYOGENIC SPACECRAFT PROPULSION
INSTANT START COMPONENT EXAMIN

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envi
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start	Flight Vent Shutoff Valve (U81)	1/2	100	Zero	30	100	GN_2, GHe 150 t
	Pneumatic Supply GHe Fill Valve (U82)	1/4	< 1	NA			GHe 140 t
	GHe/LF_2 Pressurization SOV. Expulsion Pressurant to LF_2 Tank (U83)	5/8	< 10	NA	30	100	GF_2, GHe 150 t
	GHe Pressurization Start Valve (U84)	1	< 10	NA	30	100	GHe 37 to

NOTE: The schematic containing these subsystems is presented in Volumn IIA, Page 3-49, Figure 3-17.

Table 6-10

AFT PROPULSION SUBSYSTEMS – OMPONENT EXAMINATION (U)

ONFIDENTIAL)

kage	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
quid	M-III	M-IV						
ero	30	100	GN_2, GH_2, GHe 150 to 580°R	U81	Same as Flight Vent (U41) Table 6.2			Essentially same as flight vent (U41), Table 6.2
A			GHe 140 to 580°R	U82-1	Piloted, Spherical Globe, Magnetic Latching, Integral Filter	Modification Required	Minor	(1) Low leakage (2) High flow capacity (3) Qual. for cryo temp.
				U82-2	Cryo GHe, SOV, Dual Push-Pull Solenoid Magnetic Latching 1/4-inch 1/6 sccm	Modification Required	Minor	(1) Low leakage (2) No sliding part, less susceptible to contamination (3) Must be qualified for high pressure (4) Low flow capacity
IA	30	100	GF_2, LF_2 GHe 150 to 580°R	U83-1	Flexure Guided Poppet, Dual Solenoids, Soft Seat, Storable Propellant 5/8-inch 1/6 sccm	Modification Required	Minor	(1) No sliding parts, less susceptible to contamination (2) High flow capacity (3) All-welded construction (4) Dirt traps at a minimum (5) Low leakage (6) Teflon seat may be replaced (7) Slightly higher pressure upgrading (8) Appears suitable
IA	30	100	GHe 37 to 580°R	U84	Same as GHe/LF_2 Pressurization SOV (U83)	Modification Required	Moderate	(1) No sliding parts, less susceptible to contamination (2) Low flow capacity (3) Low leakage (4) Pressure upgrade required

Figure 3-17.

Table 6-10 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envi
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start (cont.)	GHe Fill SOV Pressurant (U85)	3/8	1	NA	30	100	GHe, 37 to
	GHe Pressurant Supply Relief Valve (U86)	1/4	NA	NA	30	100	GHe 37 to
	GHe Pneumatic Supply Relief Valve (U87)	1/4	NA	NA	30	100	GHe 140 to
	GHe Pneumatic Supply Valve, Isolates Pneumatic Supply From System (U88)	3/8	< 5	NA	30	100	GHe 140 to

able 6-10 (Cont.)
CONFIDENTIAL)

age	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
uid	M-III	M-IV						
A	30	100	GHe, GH_2 37 to 580°R	U85-1	Piloted Poppet, Metal to Metal Seat 3/8-inch	Reusable	None	(1) Pressure assisted actuation (2) Heavy for application (3) Appears suitable
				U85-2	Piloted Poppet, Globe LO_2, GH_2, LH_2, GO_2 SOV Soft Seat 3/8-inch	Modification Required	Minor	(1) Low leakage (2) Requal to higher pressure but no mods anticipated (3) Relatively susceptible to contamination (4) May generate significant contamination
				U85-3	Balanced Poppet, Globe, Kel F Seat GHe, SOV at LH_2 Temperature 3/8-inch	Reusable	None	(1) Low weight (2) High flow capacity (3) Appears suitable
A	30	100	GHe 37 to 580°R	U86-1	Cold GHe Fill Module SOV and Relief, Soft Seats, 1/2-inch 1/6 sccm	Modification Required	Minor	(1) Two valves in one module (2) Reset relief pressure (3) Heavier than necessary (4) Appears suitable
				U86-2	Metal to Metal Seat, GHe Relief Valve 3/8-inch	Modification Required	Minor	(1) Light weight (2) Upgrade pressure (3) May have to be temperature compensated
A	30	100	GHe 140 to 580°R	U87	Same as GHe Pressurant Supply Relief Valve (U86)			Same as U86 except (1) Units are somewhat oversize (2) U86-1 appears suitable
A	30	100	GHe 140 to 580°R	U88-1	Piloted, Spherical Globe, Magnetic Latching, Integral Filter 3/8-inch	Modification Required	Minor	(1) Low leakage (2) High flow capacity
				U88-2	Piloted Poppet, Globe LO_2, GH_2, LH_2, GO_2 SOV, Soft Seat 3/8-inch	Modification Required	Minor	Same as (U85) except (1) Pressure upgrade anticipated

CONFIDENTIAL

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-10 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Env
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start (cont.)							
	GH_2/LH_2 Feedline Coolant SOV. Prevents Flow on Ground (U89)	1/3	100	Zero	30	100	GH_2 30 t
	LF_2 Ground Vent and Relief. Permits Purging and Filling on Ground and Triple Redundancy Backup Relief in flight (U92)	1-1/2	20	Zero	30	100	GH_2 LF_2 150
	LF_2 Fill SOV (U93)	2	20	Zero	30	100	GN_2/ LF_2 150 t
	LH_2 Ground Vent and Relief (U94)	2	100	None	30	100	GN_2, GH_2, 37 to

Table 6-10 (Cont.)
(CONFIDENTIAL)

...age	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
...uid	M-III	M-IV						
				U88-3	Same as U85-1 and U85-3			(1) Same as U85-1 and U85-3 (2) Appear suitable
...ro	30	100	GH_2, LH_2 30 to 580°R	U89	Same as GH_2 Feedline Coolant SOV (U40, 49) Table 6-2			(1) Same as (U40, U49), Table 6-2 (2) Appear suitable
...ro	30	100	GH_2, GF_2 LF_2 150 to 580°R	U92-1	Pneumatic, all Welded, Metal to Metal Lip Seal LF_2 Service 2-inch	Reusable	None	(1) Low contaminant generation (2) No sliding surfaces (3) High flow capacity (4) Low seat stress (5) Readily cleanable (6) Machined bellows (7) Large envelope (8) Not qual'd (9) Appears suitable
...ro	30	100	GN_2/GF_2 LF_2 150 to 580°R	U-93-1	All Welded Construction Pneumatic, Lip Seals, Soft Metal Seat, LF_2 Service 2-inch 0.4 sccm	Reusable	None	(1) Low contamination generation (2) No sliding surfaces (3) Moderate seat stress (4) Readily cleanable (5) Welded bellows may be replaced (6) Large envelope (7) Not qual'd (8) Appears suitable
...ne	30	100	GN_2, GHe, GH_2, LH_2 37 to 500°R	U94-1	Piloted Pneumatic, Lip Seal, Soft Seat, LH_2, LO_2 Vent and Relief 2-1/2-inch	Modification Required	Minor	(1) High flow capacity (2) Integral filter (3) Increase pressure setting (4) Susceptible to contaminant (5) Appears suitable
				U94-2	Same as U34, Table 6-2			(1) Same as (U34) Table 6-2 (2) Appears suitable

CONFIDENTIAL

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-10 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envi
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start (cont.)	LH_2 Fill SOV (U95)	2	100	None	30	100	GN_2 GH_2 37 to
	GHe/LF_2 Oxidizer Pressurization Regulator. Regulates Expulsion Pressurant to LF_2 Tank (RG81)	5/8	<10	NA	30	100	GN_2 , GF_2 150 t

1

ble 6-10 (Cont.)
ONFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-III	M-IV						
30	100	GN_2, GHe GH_2, LH_2 37 to 500°R	U95-1	Angle Poppet, Pneumatic, Soft Lip Seal, LH_2, LO_2 SOV 2-inch 500 sccm	Modification Required	Minor	(1) High leakage (2) Should have good wear characteristics (3) Appears suitable
			U95-2	Double Seal Ball, Pneumatic, LH_2 SOV Soft Seat 2-inch 160 sccm	Modification Required	Minor	(1) Reduced susceptibility to contaminant (2) Main seat subject to wear (3) May generate significant contaminant (4) Appears suitable (5) Leakage high
30	100	GN_2, GHe, GF_2 150 to 580°R	RG81-1	Piloted Poppet, Two Series Redundant Units, GHe Regulator 5/8 → 1-inch 40 sccm	Modification Required	Moderate	(1) High flow capacity (2) Integral filter (3) Heavy (4) Many O-ring seals subject to wear (5) Susceptible to contaminant detriment (6) Qual for low temperature (7) Replace seals for compatibility (8) Oversize (9) Pressure setting must be reduced
			RG81-2	Poppet, Globe, O Ring Seat, GHe Regulator 1/2-inch	Modification Required	Moderate	(1) Low weight (2) Sensitive to contaminant (3) Will generate contaminant (4) Several O-ring seals must be replaced (5) Reset regulator setting (6) May wear faster than other designs (7) Low flow capacity
			RG81-3	Dual and Single Seats, Integral Filter Spring Reference Gaseous Regulator 3/8 → 1/2-inch	Modification Required	Moderate	(1) Simple operation (2) Less susceptible to contaminant (3) No O-ring in contact with fluid (4) Low flow capacity (5) Static seals should be replaced for increased reliability

CONFIDENTIAL

2

CONFIDENTIAL

Table 6-10 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environm
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start (cont.)	GH_2/LH_2 Expulsion Regulator. Regulates Expulsion Pressure to LH_2 Tank (RG82)	5/8	<10	NA	30	100	GN_2, GH GH_2, LH 37 to 580°
	GHe Pressurant Regulator. Reduces Pressure RG83)	1	<5	NA	30	100	GN_2, GHe 37 to 580°
	GHe/LH_2 Pressure Regulator. Regulates Pre-pressurization GHe to LH_2 Tank (RG84)	1	100	NA	30	100	GN_2, GHe GH_2 37 to 580°
	GHe Pneumatic Supply Regulator (RG85)	3/8	<5	NA	30	100	GHe 140 to 580
	LH_2 Expansion Valve Regulator. Subcools Hydrogen Through TCU Vent (RG86)	1/4	25	NA	30	100	GN_2, GH GH_2, LH 37 to 580

able 6-10 (Cont.)
(CONFIDENTIAL)

ge	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
ld	M-III	M-IV						
	30	100	GN_2, GHe, GH_2, LH_2 37 to 580°R	RG82	Same as GHe/LF_2 Oxidizer Pressurization Regulator (RG81)	Modification Required	Minor	Same as RG81 except no compatibility problems.
	30	100	GN_2, GHe 37 to 580°R	RG83	Same as GHe/LF_2 Oxidizer Pressurization Regulator (RG81)	Modification	Minor	Same as RG81 except (1) That unit is not overweight, (2) Pressure setting increases
	30	100	GN_2, GHe GH_2 37 to 580°R	RG84	Same as GH_2/LH_2 Expulsion Regulator (RG82)	Modification Required	Minor	Same comments as RG82 except (1) Unit not overweight (2) Unit not oversize
	30	100	GHe 140 to 580°R	RG85-1	Directly Modulated Poppet, Diaphragm, Sensing, Integral Filter, GHe Regulator 3/8 inch	Modification Required	Moderate	(1) Integral relief serves as U86) (2) Light weight (3) Requal for low temp (4) Low flow capacity (5) May have to replace diaphragm
				RG85-2	Dual & Single Seats, Integral Filter, Spring Reference Gaseous Regulator 3/8 — 1/2 inch	Modification Required	Minor	(1) Simple operation (2) Less susceptible to contamination (3) No O-rings in contact with fluid (4) Increase regulated setting (5) Requal for low temp (6) Should be long wearing
	30	100	GN_2, GHe GH_2, LH_2 37 to 580°R	RG86	Same as TCU Expansion Valve (RG20) Table 6-2			Same as RG20, Table 6-2

CONFIDENTIAL

2

PRECEDING PAGE BLANK-NOT FILMED.

Table 6-10 (Cont.

(CONFIDENTIAL

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start (cont.)	GHe/LF_2 Pre-Pressurization Regulator (RG87)	1/4	<10	NA	30	100	GN_2, G 150 to
	GHe/LF_2 Isolation Check Valves. Prevents fluorine vapors from diffusing into pressurization line (CK81)	3/4	<1	None	30	80	GHe, Gl GF_2, L 150 to 5

1

Table 6-10 (Cont.)
(CONFIDENTIAL)

e	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
d	M-III	M-IV						
	30	100	GN_2, GHe, GF_2 150 to 580oR	RG87-1	Piloted Poppet, Metal to Metal Seat, Spring Loaded Diaphragm Reference 1/4 → 3/8 inch	Modification Required	Major	(1) Can be all-welded (2) Mylar seat and diaphragm replacement (3) Reference spring may have vibration problems (4) Pilot spring in fluid stream (5) Reduces regulated pressure substantially
				RG87-2	Same as GHe/LF_2 Oxidizer Pressurization Regulator (RG81)	Modification Required	Moderate	Same as RG81 comment except (1) Slightly oversize (2) Slightly overweight
				RG87-3	2 Seats Series Reundant, Temperature Compensated, Integral Filter, GN_2 Regulator Bellows Sealed Sensing Element	Modification Required	Moderate	(1) Redundant (2) Simple operation (3) Compatible with N_2O_4 fumes (4) Less susceptible to contamination than other designs (5) Modify for temperature if necessary (no problems anticipated) (6) Leakage may be improved.
	30	80	GHe, GN_2 GF_2, LF_2 150 to 580oR	CK81-1	Soft Seat, Guided Poppet, GHe Check Valve 3/8 inch	Technology Development	N. A.	(1) High flow capacity (2) Can be all-welded (3) Should have long life (4) Replace mylar seat and gaskets (5) Relatively heavy (6) Spring should be isolated from fluid
				CK81-2	Soft Lip Seat, GH_2 Check Valve 3/4 inch	Technology Development	N. A.	(1) High flow capacity (2) Long life expected (3) Teflon seat and gasket replaced (4) Isolate spring from fluid (5) Cres construction preferred (6) Relatively heavy (7) May be susceptible to contamination

2

Table 6-10 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start (cont.)	GHe/LH_2 Isolation Check Valve. Prevents hydrogen vapors from diffusing into LH_2 pressurization line. (CK82)	1	100	None	30	30	GHe, G GH_2, L 37 to 58
	GHe Pressurant Fill Disconnect (QD81)	3/8	NA	NA	30	100	GN_2, GH 37 to 58

1

e 6-10 (Cont.)
NFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-III	M-IV						
30	80	GHe, GN_2 GH_2, LH_2 37 to 580°R	CK82-1	Soft Seat, LO_2 Check Valve 1-1/2 inch	Modification Required	Minor	(1) Low leakage (2) High flow capacity (3) Moderately low cracking ΔP (4) May generate significant contaminant (5) Somewhat oversize (6) Requal for LH_2 temperature (no problems anticipated)
			CK82-2	Soft Lip Seat, GH_2 Check Valve 3/4 inch	Reusable	None	(1) Long life anticipated (2) Relatively heavy (3) Appears suitable
			CK82-3	Poppet, Soft Seat, GHe Check Valve 3/8 inch	Modification Required	Minor	(1) Long life expected (2) Requal to LH_2 temperature (no problems expected) (3) Low flow capacity (4) May be susceptible to contamination detriment (5) Appears suitable
30	100	GN_2, GHe 37 to 580°R	QD81	Same as GHe Fill Disconnect (QD51)			Same as QD51

2

Table 6-10 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envi
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start (cont.)	GHe/LF_2 Fill Line Purge Disconnect. Permits Fluorine to be Removed From Flight Fill System (QD82)	1/4	<10 Ext	None	30	100	GN_2, 150 to
	LF_2 Fill Disconnect (QD83)	2	<10 Ext	None	30	100	GN_2, (150 to
	LH_2 Fill Disconnect (QD84)	2	<50 Ext	None	30	100	GN_2, (LH_2 37 to 5
	LH_2 Ground Vent Disconnect (QD85)	2	<50 Ext	None	30	100	GN_2, C LH_2 37 to 5
	LF_2 Vent Disconnect (QD86)	1-1/2	<10 Ext	None	30	100	GN_2, C 150 to
	GHe/LH_2 Fill Lines Purge Disconnect (QD87)	1/4	100	NA	30	100	GN_2, G LH_2 37 to 58
	GHe Pneumatic Fill Disconnect (QD88)	1/4	NA	NA	30	100	GN_2, G 140 to 3
	LN_2 Ground Vent-Free Supply Disconnect (QD89)	1/4	NA	NA	30	100	GN_2, L 150 to 5

Table 6-10 (Cont.)
(CONFIDENTIAL)

kage	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
iquid	M-III	M-IV						
one	30	100	GN_2, GF_2, LF_2 150 to 580°R	QD82		Technology Development	N. A.	
one	30	100	GN_2, GF_2, LF_2 150 to 580°R	QD83	Fluorine 2-Inch	Reusable	None	(1) Designed for fluorine service (2) Appears suitable
one	30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	QD84	Check Valve in Airborne and Ground Halves LO_2 and LN_2 Service	Modification Required		(1) Light weight (2) Modify for temperature if necessary (3) Remove flight check valve
one	30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	QD85	Same as LH_2 Fill Disconnect (QD84)			Same comments as QD84 except: (1) No temperature problems (2) Appears suitable
one	30	100	GN_2, GF_2, LF_2 150 to 580°R	QD86	Same as LH_2 Ground Vent Disconnect (QD85)			Same as QD83 except: (1) Slightly oversize (2) Appears suitable
IA	30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	QD87	Same as GHe/LF_2 Fill Line Purge Disconnect (QD82)			Same as QD82
IA	30	100	GN_2, GHe 140 to 580°R	QD88	Same as GHe Pressurant Fill Disconnect (QD81)			Same as QD81 except: (1) Slight oversize (2) Pressure range is proper (3) Appears suitable
IA	30	100	GN_2, LN_2 150 to 580°R	QD89	Same as GHe, LF_2 Fill Line Purge Disconnect (QD82)			Same as QD82 except: (1) Slightly oversize (2) Appears suitable (3) No compatibility problems

Table 6-10 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		I
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystems Instant Start (cont.)	GN_2 Vehicle Purge Disconnect (QD90)	3/4	NA	NA	30	100	GN 40
	GHe Ground Control Disconnect (QD92)	3/8	NA	NA	30	100	GN 40

able 6-10 (Cont.)

CONFIDENTIAL)

Leakage n)	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
Liquid	M-III	M-IV						
NA	30	100	GN_2 400 to 580°R	QD90	Double checking remote disconnect, soft seat, Cold GHe disconnect 3/8 inch			(1) Low flow capacity (2) Heavier than necessary (3) Appears suitable
NA	30	100	GN_2, GHe 400 to 580°R		Same as GHe Fill Disconnect (QD51)			Same as QD51

2

PRECEDING PAGE BLANK NOT FILMED.

CONFIDENTIAL

Table 6-11

CRYOGENIC SPACECRAFT (LF_2/LH_2) PROPU
NORMAL START COMPONENT EXAM

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		E
			Gas	Liquid	M-I	M-II	
Propulsion Subsystem Normal Start	LF_2 Pressurization Directional Control Valve Switches Pressurant Supply from Prepressurant to Expulsion (U101)	5/8	< 10	NA	30	100	GN 155
	GHe/LH_2 Prepressurization SOV Regulates prepressurant to LH_2 tank (U102)	1/2	100	NA	30	100	GN 37 t
	LF2, Pre-Valve Isolates LF_2 from Engine Interface (U103)	3	20	Zero	30	100	GN_2 150
	LH_2 Pre-Valve Isolates LH_2 from Engine Interface (U104)	2-1/2	100	Zero	30	100	GN_2 LH_2 37 t
	LH_2 Fill SOV (U105)	2	100	None	30	100	GN_2 LH_2
	GHe Pneumatic Supply Fill Valve (U106)	1/4	< 1	NA	30	100	GN_2 140
	GHe Pressurant Supply Relief Valve (U106A)	1/4	NA	NA	30	100	GN_2 LF_2 37 t

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-51, Figure 3-18.

Table 6-11

(LF2/LH2) PROPULSION SUBSYSTEMS –
OMPONENT EXAMINATION (C)

ONFIDENTIAL)

akage	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
iquid	M-I	M-II						
NA	30	100	GN_2, GHe 155 to 580°R	U101-1	Vol IV, Table 8			
NA	30	100	GN_2, GHe 37 to 580°R	U102	Same as GHe/LF_2 Pressurization SOV (U83) Table 6-9			Same as (U83), Table 6-9
Zero	30	100	GN_2, GF_2, LF_2 150 to 580°F	U103-1	Poppet 3 inch 1.7 sccm			
Zero	30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	U104	Same as LH_2 Fill SOV (U95) Table 6-9			Same as U95, Table 6-9
None	30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	U105	Same as LH_2 Fill SOV (U95) Table 6-9			Same as U95, Table 6-9
NA	30	100	GN_2, GHe 140 to 580°R	U106	Same as GHe Pneumatic Fill Valve (U82) Table 6-9			Same U82, Table 6-9
NA	30	100	GN_2, GHe, GF_2 LF_2 37 to 580°R	U106A	Same as GHe Pressurant Supply Relief Valve (U86) Table 6-9			Same as U86, Table 6-9

igure 3-18.

2

CONFIDENTIAL

Table 6-11 (Cont.)

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		En
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystem Normal Start (Cont.)	GHe Pneumatic Supply Relief Valve (U107)	1/4	NA	NA	30	100	GN_2, 140 t
	GHe Pneumatic Supply Valve Isolates GHe from System (U108)	3/8	<5	NA	30	100	GHe 140 t
	GH_2/LH_2 Feedline Coolant SOV. Prevents Flow on Ground (U109)	1/8	100	Zero	30	100	GH_2, 30 to
	GH_2 Flight Vent Valve (U110)	1/4	100	Zero	30	100	GN_2, 150 t
	LH_2 Ground Vent & Relief (U111)	2	100	None	30	100	GN_2, LH_2 3.7 t
	LF_2 Ground Vent & Relief (U112)	1-1/2	20	Zero	30	100	GN_2, 150 t
	LF_2 Fill SOV (U113)	2	20	Zero	30	100	GN_2 150
	GHe Pressurization Start Valve Isolates GHe from System (114)	1	<10	NA	30	100	GN 37 t
	GHe Fill SOV Pressurant Supply Fill (U115)	3/8	<1	NA	30	100	GN_2 37 t

PRECEDING PAGE BLANK-NOT FILMED.

e 6-11 (Cont.)
NFIDENTIAL)

eakage	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
Liquid	M-III	M-IV						
NA	30	100	GN_2, GHe 140 to $580^{\circ}R$	U107	Same as GHe Pressurant Supply Relief Valve (U86) Table 6-9			Same as U86, Table 6-9
NA	30	100	GHe 140 to $580^{\circ}F$	U108	Same as GHe Pneumatic Supply Valve (U88) Table 6-9			Same as U88, Table 6-9
Zero	30	100	GH_2, LH_2 30 to $580^{\circ}R$	U109	Same as GH_2/LH_2 Feedline Coolant SOV (U89) Table 6-9			Same as U89 Table 6-9
Zero	30	100	GN_2, GHe, GH_2 150 to $580^{\circ}R$	U110	Same as GH_2 Flight Vent Valve (U81) Table 6-9			Same as U81 Table 6-9
None	30	100	GN_2, GH_e, GH_2 LH_2 3.7 to $580^{\circ}R$	U111	Same as LH_2 Ground Vent & Relief Table 6-9 (U94)			Same as U94, Table 6-9
Zero	30	100	GN_2, GF_2, LF_2 150 to $580^{\circ}R$	U112	Same as LF_2 Ground Vent & Relief (92) Table 6-9			Same as U92, Table 6-9
Zero	30	100	GN_2, GF_2, LF_2 150 to $580^{\circ}R$	U113	Same as LF_2 Fill SOV (U93) Table 6-9			Same as U93, Table 6-9
NA	30	100	GN_2, GHe 37 to $580^{\circ}R$	U114	Same as GHe/LF_2 Pressurization SOV (U84) Table 6-9			Same as U84, Table 6-9
NA	30	100	GN_2, GHe 37 to $580^{\circ}R$	U115	Same as GHe Fill SOV (U85) Table 6-9			Same as U85, Table 6-9

2

Table 6-11 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		F
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystem Normal Start (Cont.)	GHe Fill SOV. Burner Supply, Pressurant Fill Valve (U116)	1/8	<1	NA	30	100	GH 40
	GHe Relief Valve. Burner Supply Pressurant Relief (U117)	1/8 → 1/4	NA	NA	30	100	GH 40
	GHe Press SOV. Isolates Burner Supply Pressurant (U118)	1/8	<1	NA	30	100	GH 40
	N_2O_4 Relief Valve. Burner Oxidizer Tank Relief (U119)	1/8	NA	NA	30	100	GH 40
	N_2O_4 Fill SOV Burner Supply Oxidizer Fill (U120)	1/8	<1	None	30	100	GH 40
	N_2O_4 Tank SOV Burner Oxidizer Start Valve (U121)	1/8	<5	None	30	100	GH 40
	50-50 Fill SOV Burner Supply Fuel Fill (U122)	1/8	<1	None	30	100	GH 40
	50-50 Tank SOV Burner Fuel Start Valve (U123)	1/8	<5	None	30	100	GH 40

ble 6-11 (Cont.)
ONFIDENTIAL)

eakage)	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
Liquid	M-III	M-IV						
NA	30	100	GHe 400 to 580^{o}R	U116	Same as GHe Pressurant SOV (U201) Table 6-8			Same as U201, Table 6-8
NA	30	100	GHe 400 to 580^{o}R	U117	Same as GHe Relief Valve Valve (U102) Table 6-7			Same as U102, Table 6-7
NA	30	100	GHe 400 to 580^{o}R	U118	Same as GHe Pressurant SOV (U201) Table 6-8			Same as U201, Table 6-8
NA	30	100	GHe, N_2O_4 400 to 580^{o}R	U119	Same as N_2O_4 Relief Valve (U104) Table 6-7			Same as U104, Table 6-7
None	30	100	GHe, N_2O_4 400 to 580^{o}R	U120-1	Same as N_2O_4 Fill SOV (U105) Table 6-7			Same as U105, Table 6-7
None	30	100	GHe, N_2O_4 400 to 580^{o}R	U121	Same as N_2O_4 Fill SOV (U105) Table 6-7			Same as U105, Table 6-7
None	30	100	GHe, 50-50 400 to 580^{o}R	U122	Same 50-50 Fill SOV (U106) Table 6-7			Same as U106, Table 6-7
None	30	100	GHe, 50-50 400 to 580^{o}R	U123	Same as 50-50 Fill SOV (U106) Table 6-7			Same as U106, Table 6-7

2

Table 6-11 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)	
			Gas	Liquid	M-III	M-IV
Propulsion Subsystem Normal Start (Cont.)	50-50 Relief Valve Burner Fuel Tank Relief (U124)	1/8	NA	NA	30	100
	N_2O_4 Fill Vent SOV (U125)	1/8	<1	None	30	100
	50-50 Fill Vent SOV (U126)	1/8	<1	None	30	100
	GHe/LF_2 Pressurization Regulator (RG101)	5/8	<10	NA	30	100
	GH_2/LH_2 Expulsion Regulator (RG102)	5/8	<10	NA	30	100
	GHe Pressurant Regulator Reduces pressure up-stream of heat exchanger (RG103)	1	<10	NA	30	100
	GHe/LH_2 Prepressurization Regulator (RG104)	1	<10	NA	30	100
	GHe Pneumatic Supply Regulator (RG105)		<1	NA	30	100
	LH_2 Expansion Regulator. Subcools hydrogen through TCU vent (RG106)	1/4	25	86	30	100

able 6-11 (Cont.)
CONFIDENTIAL)

Leakage m)	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
Liquid	M-III	M-IV						
NA	30	100	GHe, 50-50 400 to 580oR	U124	Same as MMH Tank Relief Valve (U205) Table 6-8			Same as U205, Table 6-8
None	30	100	GHe, N_2O_4 400 to 580^oR	U125	Same as N_2O_4 Vent SOV (U207)			Same as U207
None	30	100	GHe, 50-50 400 to 580^oR	U126	Same as N_2O_4 Vent SOV (U207) Table 6-8			Same as U207, Table 6-8
NA	30	100	GN_2, GHe, GF_2 150 to 580^oR	RG101	Same as GHe/LF_2 Oxidizer Pressurization Regulator (RG81)			Same as RG81
NA	30	100	GN_2, GHe, GH_2 LH_2 37 to 580^oR	RG102	Same as GHe/LF_2 Oxidizer Pressurization Regulator (RG81) Table 6-9			Same as RG81, Table 6-9
NA	30	100	GHe 37 to 580^oR	RG103	Same as GHe Pressurant Regulator (RG83) Table 6-9			Same as RG83, Table 6-9
NA	30	100	GN_2, GHe, GH_2 37 to 580^oR	RG104	Same as GHe Pressurant Regulator (RG83) Table 6-9			Same as RG83, Table 6-9
NA	30	100	GHe 140 to 580^oR	RG105	Same as GHe Pneumatic Supply Regulator (RG85) Table 6-9			Same as RG85, Table 6-9
86	30	100	GN_2, GHe, GH_2 LH_2 30 to 580^oR	RG106	Same as LH_2 Expansion Regulator (RG86) Table 6-9			Same as RG86, Table 6-9

2

Table 6-11 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystem Normal Start (Cont.)	GHe Pressure Regulator Burner Supply Pressurant Regulator (RG107)	1/8	<1	NA	30	100	GHe 400 to
	LF_2 Bleed Check Valve. Permits feedline pressure relief between burns. (CK101)	1/8→1/4	<10	None	30	100	GN_2, G 150 to
	LH_2 Bleed Check Valve. Permits feedline pressure relief between burns. (CK102)	1/8→1/4	50	None	30	100	GN_2, G LH_2 37 to 5
	GHe/LH_2 Isolation Check Valve. Prevents LH_2 from entering pressurant line. (CK103)	1	100	None	30	80	GN_2, G LH_2 37 to 5
	GHe/LF_2 Isolation Check Valve. Prevents LF_2 from entering pressurant line. (CK105)					80	GN_2, G 150 to 5
	N_2O_4 Check Valve. Prevents N_2O_4 vapor from diffusing into pressurant supply. (CK106, 107)	1/8→1/4	<1	None	30	80	GN_2, N 400 to 5
	50-50 Check Valve. Prevents N_2O_4 vapor from diffusing into pressurant supply (CK108, 109)	1/8→1/4	<1	None	30	80	GN_2, N 400 to 5

able 6-11 (Cont.)

CONFIDENTIAL)

Leakage m)	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
Liquid	M-III	M-IV						
NA	30	100	GHe 400 to 580°R	RG107	Same as GHe Pressurant Regulator (RG501)			Same as RG501
None	30	100	GN_2, GF_2, LF_2 150 to 580°R	CK101		Technology Development	N. A.	
None	30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	CK102				
None	30	80	GN_2, GHe, GH_2 LH_2 37 to 580°R	CK103	Same as GHe/LH_2 Isolation Check Valve (CK82) Table 6-9			Same as CK82, Table 6-9
		80	GN_2, GF_2, LF_2 150 to 580°R	CK105	Same as GHe/LF_2 Isolation Check Valve (CK81) Table 6-9			Same as CK81, Table 6-9
None	30	80	GN_2, N_2O_4 400 to 580°R	CK106 CK107	Same as GHe/N_2O_4 Quad Check Valve (CK202) Table 6-8			Same as CK202, Table 6-8
None	30	80	GN_2, N_2O_4 400 to 580°R	CK108 CK109	Same as GHe/MMH Quad Check Valve (CK201) Table 6-8			Same as CK201, Table 6-8

2

Table 6-11 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystem Nominal Start (Cont.)	GHe Pressurant Fill Disconnect (QD101)	3/8	NA	NA	30	100	C 3
	GHe/LF_2 Fill Line Purge Disconnect (QD102)	1/4	<10 Ext	NA	30	100	C 1
	LF_2 Fill Disconnect (QD103)	2	<10 Ext	None	30	100	C 1
	LH_2 Fill Disconnect (QD104)	2	<50	None	30	100	G G 3
	LH_2 Ground Vent Disconnect (QD105)	2	<50 Ext	None	30	100	G L 3
	LF_2 Vent Disconnect (QD106)	1-1/2	<10 Ext	None	30	100	G 1
	GHe/LH_2 Fill Line Purge Disconnect (QD107)	1/4	100 Ext	NA	30	100	G L 3
	GHe Pneumatic Fill Disconnect (QD108)	1/4	NA	NA	30	100	G 1
	LN_2 Ground Vent-Free Supply Disconnect (QD109)	1/4	NA	NA	30	100	G 1

1

able 6-11 (Cont.)
CONFIDENTIAL)

Leakage cm)	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
Liquid	M-III	M-IV						
NA	30	100	GN_2, GHe 37 to 580oR	QD101	Same as GHe Pressurant Fill Disconnect (QD81) Table 6-9			Same as QD81, Table 6-9
NA	30	100	GN_2, GF_2, LF_2 150 to 580oR	QD102	Same as GHe/LF_2 Fill Line Purge Disconnect (QD82) Table 6-9			Same as QD82, Table 6-9
None	30	100	GN_2, GF_2, LF_2 150 to 580°R	QD103	Same as LF_2 Fill Disconnect (QD83) Table 6-9			Same as QD83, Table 6-9
None	30	100	GN_2, GHe, LH_2 GH_2 37 to 580°R	U104	Same as LH_2 Fill Disconnect (QD84) Table 6-9			Same as QD84
None	30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	U105	Same as LH_2 Fill Disconnect (QD84)			Same as QD84
None	30	100	GN_2, GF_2, LF_2 150 to 580°R	QD106	Same as LF_2 Fill Disconnect (QD83)			Same as QD83
NA	30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	QD107	Same as GHe/LH_2 Fill Line Purge Disconnect (QD87)			Same as QD87
NA	30	100	GHe 140 to 580°R	QD108	Same as GHe Pneumatic Fill Disconnect (QD88)			Same as QD88
NA	30	100	GN_2, LN_2 140 to 580oR	QD109	Same as LN_2 Ground Vent-Free Supply Disconnect (QD89)			Same as QD89

2

Table 6-11 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		E
			Gas	Liquid	M-III	M-IV	
Propulsion Subsystem Normal Start (Cont.)	GN_2 Vehicle Purge Disconnect (QD110)	3/4	NA	NA	30	100	GN 400
	GHe Fill Disconnect Burner Supply Pressurant Fill QD113)	1/8	NA	NA	30	100	GH 400
	N_2O_4 Fill Disconnect Burner Supply Oxidizer Fill Disconnect (QD114)	1/8	< 20	None	30	100	GN 400
	50-50 Fill Disconnect Burner Supply Fuel Fill Disconnect QD115)	1/8	<20 Ext	None	30	100	GN 400
	N_2O_4 Fill Vent Disconnect Burner Supply Disconnect (QD116)	1/8	<20 Ext	None	30	100	GN 400
	50-50 Fill Vent Disconnect Burner Supply Disconnect (QD117)	1/8	<20 Ext	None	30	100	GN 400

le 6-11 (Cont.)
ONFIDENTIAL)

eakage n)	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
Liquid	M-III	M-IV						
NA	30	100	GN_2 400 to 580°R	QD110	Same as GN_2 Vehicle Purge Disconnect (QD90) Table 6-9			Same as QD90
NA	30	100	GHe 400 to 580°R	QD113	Same as GHe Fill Disconnect (D101) Table 6-7			Same as D101
None	30	100	GN_2, N_2O_4 400 to 580°R	QD114	Same as N_2O_4 Fill Disconnect (D102) Table 6-7			Same as D102
None	30	100	GN_2, 50-50 400 to 580°R	QD115	Same as 50-50 Fill Disconnect (D103) Table 6-7			Same as D103, Table 6-7
None	30	100	GN_2, N_2O_4 400 to 580°R	QD116	Same as N_2O_4 Fill Vent Disconnect (D104)			Same as D104
None	30	100	GN_2, 50-50 400 to 580°R	QD117	Same as 50-50 Fill Vent Disconnect (D105) Table 6-7			Same as (D105)

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-12

CRYOGENIC AND STORABLE SPACECRAFT ATTITU
N_2O_4/MMH COMPONENT EXAMIN.
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probab Life (fl	
			Gas	Liquid	M-III	M
Attitude Control Subsystem FDL-5 Spacecraft N_2O_4/MMH	Pressurization Fill SOV (U300)	1/8			30	1
	GHe Pressurant SOV (U301, 302)	1/8			30	1
	GHe Pressurant SOV (U303)	1/8			30	1
	MMH Tank Relief Valve (U305)	1/8			30	1
	N_2O_4 Tank Relief Valve (U306)	1/8			30	1
	N_2O_4 Vent SOV (U307)	1/8			30	1
	MMH Vent SOV (U308)	1/8			30	1
	MMH Pre-valve (U309, 311)	1/4			30	1
	N_2O_4 Pre-valve (U310, 312)	1/4			30	1
	N_2O_4 File and Drain SOV (U313)	1/2			30	1

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-55, Figure 3-19.

1

Table 6-12

ECRAFT ATTITUDE CONTROL SUBSYSTEM
ONENT EXAMINATION (C)

NFIDENTIAL)

ble Leakage (sccm)		Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
	Liquid	M-III	M-V						
		30	10	GHe 400 to 580°R	U300	Same as GHe Pressurant SOV (U201) Table 6-8			(1) Same as U201 (2) Appears suitable
		30	10	GHe 400 to 580°F	U301 U302	Same as GHe Pressurant (U201)			(1) Same as U201 (2) Appears suitable
		30	10	GHe 400 to 580°R	U303	Same as GHe Pressurant (U203)			(1) Same as U203 (2) Appears suitable
		30	10	GHe, MMH 400 to 580°R	U305	Same as MMH Tank Relief Valve (U205)			(1) Same as U205 (2) Appears suitable
		30	10	GHe, N_2O_4 400 to 580°R	U306	Same as N_2O_4 Tank Relief Valve (U206)			(1) Same as U206 (2) Appears suitable
		30	10	GHe, N_2O_4 400 to 580°R	U307	Same as N_2O_4 Vent SOV (U207)			(1) Same as U207 (2) Appears suitable
		30	10	GHe, MMH 400 to 580°R	U308	Same as MMH Vent SOV (U208)			(1) Same as U208 (2) Appears suitable
		30	10	GHe, MMH 400 to 580°R	U309 U311	Same as MMH Cluster (U215)			(1) Same as U215 (2) Appears suitable
		30	10	GHe, N_2O_4 400 to 580°R	U310 U312	Same as N_2O_4 Cluster (U218)			(1) Same as U218 (2) Appears suitable
		30	10	GHe, N_2O_4 400 to 580°R	U313	Same as N_2O_4 Fill and Drain SOV (U213)			(1) Same as U213 (2) Appears suitable

Figure 3-19.

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-12 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probal Life (fl	
			Gas	Liquid	M-III	M
Attitude Control Subsystem FDL-5 Spacecraft N_2O_4/MMH (cont.)	MMH Fill and Drain SOV (U314)	1/2			30	[illegible]
	MMH Cluster SOV (U315, 317)	1/4			30	[illegible]
	N_2O_4 Cluster SOV (U316, 318)	1/4			30	1
	GHe Pressurization Regulator (RG300)	1/8			30	1
	GHe/MMH Quad Check Valve (CK301)	1/8			24	
	GHe/N_2O_4 Quad Check Valve (CK302	1/8			24	
	Pressurization Fill Disconnect (QD300)	1/8			30	1
	N_2O_4 Vent Disconnect (QD301)	1/8			30	1
	MMH Vent Disconnect (QD302)	1/8			30	1
	N_2O_4 Fill and Drain Disconnect (QD303)	1/2			30	1
	MMH Fill and Drain Disconnect (QD304)	1/2			30	1

1

able 6-12 (Cont.)
CONFIDENTIAL)

lowable Leakage (sccm)		Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
as	Liquid	M-III	M-V						
		30	10	GHe, MMH 400 to 580°R	U314	Same as MMH Fill and Drain SOV (U214)			(1) Same as U214 (2) Appears suitable
		30	10	GHe, MMH 400 to 580°R	U315 U317	Same as MMH Cluster SOV (U215)			(1) Same as U215 (2) Appears suitable
		30	10	GHe, N_2O_4 400 to 580°R	U316 U318	Same as N_2O_4 Cluster SOV (U218)			(1) Same as U218 (2) Appears suitable
		30	10	GHe 400 to 580°R	RG300	Same as GHe Pressurization Regulator (RG200)			(1) Same as RG200 (2) Appears suitable
		24	9	GHe, MMH 400 to 580°R	CK301	Same as GHe/MMH Quad Check Valve (CK201)			(1) Same as CK201 (2) Appears suitable
		24	9	GHe/N_2O_4 400 to 580°R	CK302	Same as GHe/N_2O_4 Quad Check Valve (CK202)			(1) Same as CK202 (2) Appears suitable
		30	10	GHe 400 to 580°R	QD300	Same as Pressurization Fill Disconnect (QD200)			Same as QD200
		30	10	GHe/N_2O_4 400 to 580°R	QD301	Same as N_2O_4 Vent Disconnect (QD201)			Same as QD201
		30	10	GH3/MMH 400 to 580°R	QD302	Same as MMH Vent Disconnect (QD202)			Same as QD202
		30	10	GHe/N_2O_4 400 to 580°R	QD303	Same as N_2O_4 Fill and Drain Disconnect (QD203)			Same as QD203
		30	10	GHe/MMH 400 to 580°R	QD304	Same as MMH Fill and Drain Disconnect (QD204)			Same as QD204

CONFIDENTIAL

2

[illegible]

CONFIDENTIAL

Table 6-13

CRYOGENIC SPACECRAFT (LF_2/LH_2) INTEGRATI
SUBSYSTEM COMPONENT EXAMIN
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Enviro
			Gas	Liquid	M-III	M-IV	
Integrated Attitude Control Subsystem LF_2/LH_2 FDL-5	GF_2 Fill Valve; Shutoff Valve for Initial Accumulator Charging (U401)	1/4			30	100	GN_2, GF 400 to 58
	GF_2 Relief Valve Protects GF_2 Accumulator (U402)	1/2			30	100	GN_2, GF 400 to 58
	GF_2 Directional Valve Controls Pump Actuation (U403)	1-3/4			12	100	GN_2, GF 400 to 58
	GH_2 Fill SOV Accumulator Initial Fill SOV (U404)	1/4			30	100	GN_2, GH 400 to 58
	GH_2 Relief Valve Protects GH_2 Accumulator (U405)	1/2			30	100	GN_2, GH 400 to 58
	GH_2 Directional Valve, Controls Pump Actuation (U406)	1-3/4			12	100	GHe, GN 400 to 58

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-57, Figure 3-20.

1

Table 6-13

/LH$_2$) INTEGRATED ATTITUDE CONTROL
PONENT EXAMINATION (C)

:ONFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-III	M-IV						
30	100	GN_2, GF_2 400 to 580°R	U401	Poppet, all metal construction, fluorine service 1/4 inch 2 sccm	Reusable	None	(1) Designed for fluorine service (2) Minimum of moving parts (3) Some sliding surfaces exposed to LF_2 (4) Appears suitable
30	100	GN_2, GF_2 400 to 580°R	U402		Technology Development	N.A.	
12	100	GN_2, GF_2 400 to 580°R	U403		Technology Development	N.A.	
30	100	GN_2, GHe, GH_2 400 to 580°R	U404-1	Metal to Metal Seat Welded Seals, CGSS SOV 1/4 inch 1.7 sccm	Reusable	None	(1) No sliding seals (2) Low suscept. to contaminant (3) Low leakage (4) Long life expected (5) Low weight (6) Appears suitable
30	100	GN_2, GHe, GH_2 400 to 580°R	U405-1	Poppet, Metal to Metal Seat, Bellows Sealed, Spring Reference, GHe Relief Valve	Reusable	None	(1) Accurate cracking press (2) Minimum sliding surfaces (3) Heavy (4) Reduce relief pressure (5) Appears suitable
			U405-2	Soft Seat, Spring reference, Integral Burst Disc, GHe Relief Valve	Modification Required	Minor	(1) Light weight (2) High flow capacity (3) Zero leakage (4) Increase cracking pressure
12	100	GHe, GN_2, GH_2 400 to 580°R	U406				

'igure 3-20.

2

Table 6-13 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Environm
			Gas	Liquid	M-III	M-IV	
Integrated Attitude Control Subsystem LF_2/LH_2 FDL-5 (cont.)	GF_2 Feed Valve. Isolates thrusters from system (U407)	1-1/4			30	100	GN_2, GF_2 400 to 580°
	GH_2 Feed Valve. Isolates thrusters from system (U408)	1-1/2			30	100	GN_2, GH_2 400 to 580°
	LF_2 Pump Suction Check Valve. (CK401)	1			30	100	GN_2, GF_2, 150 to 580°
	LF_2 Pump Discharge Check Valve (CK402)	1			30	100	GN_2, GF_2, 150 to 580°
	LH_2 Pump Suction Check Valve (CK403)	1			30	100	GN_2, GHe, 37 to 580°R
	LH_2 Pump Discharge Check Valve (CK404)	1			30	100	GN_2, GHe, LH_2 37 to 580°R
	GF_2 Burner Check Valve (CK405)	1			30	100	GN_2, GF_2 400 to 580°
	GH_2 Burner Check Valve (CK406)	1-1/2			30	100	GN_2, GH_2

1

le 6-13 (Cont.)

NFIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-III	M-IV						
30	100	GN_2, GF_2 400 to 580°R	U407		Technology Development	N.A.	
30	100	GN_2, GH_2 400 to 580°R	U408		Reusable	None	
30	100	GN_2, GF_2, LF_2 150 to 580°R	CK401	Split Flapper, Spring Loaded Closed, N_2O_4 Check Valve	Modification Required	Major	(1) Low cracking and full flow ΔP (2) No sliding parts (3) Low susceptibility to contaminant (4) Vibration could be a problem (5) Replace non-metallic seat (6) Temperature modification might be necessary
30	100	GN_2, GF_2, LF_2 150 to 580°R	CK402	Same as LF_2 Pump suction check valve (CK401)			Same as CK401
30	100	GN_2, GHe, GH_2 37 to 580°R	CK403	Same as LF_2 Pump Suction Check Valve (CK401)	Modification Required	Minor	Same as CK401 except no compatibility problems
30	100	GN_2, GHe, GH_2 LH_2 37 to 580°R	CK404	Same as LH_2 Pump Suction Check Valve (CK403)			Same as CK403
30	100	GN_2, GF_2 400 to 580°R	CK405-1	Split Flapper, Spring Loaded Closed, N_2O_4 Check Valve	Modification Required	Major	(1) High flow capacity (2) No sliding surfaces (3) Low weight (4) Seat may be replaced (5) Vibration may be a problem
30	100	GN_2, GH_2	CK406	Same as GF_2 Burner Check Valve (CK405)	Modification Required	Minor	Same as CK405 except no compatibility problem

Table 6-13 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Env
			Gas	Liquid	M-III	M-IV	
Integrated Attitude Control Subsystem LF_2/LH_2 FDL-5 (cont.)	GF_2 Pressure Regulator. Regulates accumulator output (RG401)	1-1/4			30	100	GN_2, 400 t
	GH_2 Pressure Regulator Regulates accumulator output (RG402)	1-1/4			30	100	GN_2, 400 to
	GF_2 Fill Disconnect (QD401)	1/8			30	100	GN_2, 400 to

ble 6-13 (Cont.)
CONFIDENTIAL)

akage	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
Liquid	M-III	M-IV						
	30	100	GN_2, GF_2 400 to 580°R	RG401		Technology Development	N. A.	
	30	100	GN_2, GH_2 400 to 580°R	RG402	Poppet, aluminum 1.3 in.	Modification Required	Minor	
	30	100	GN_2, GF_2 400 to 580°R	QD401				

2

Table 6-14

SUMMARY OF COMPONENT AVAILABILITY
FOR THE CRYOGENIC SPACECRAFT (C)

(CONFIDENTIAL)

Component Class	General Conclusions
Liquid Valves	Suitable components are available for liquid hydrogen, with modifications. Previous fluorine valves indicate that suitable components can be developed.
Vent and Relief Valves	Suitable components are available for liquid hydrogen, with modifications. Previous valve investigations indicate components can be developed.
Thermal Conditioning Units	Required for liquid hydrogen only. Units of approximately the required size are under development.
Vent Disconnects	Suitable components are available for hydrogen. Fluorine component development has indicated solutions.
Fill and Drain Disconnects	Suitable components are available for hydrogen. Component development for fluorine possible.
Regulators	Suitable components available. Additional development work is necessary for fluorine-compatible regulators.
Pressurization Valves	Suitable components are available for both hydrogen and fluorine. Fluorine compatibility is not required.
Pressure Switches	Lifetime extensions are required. Additional development for fluorine compatibility is considered required.
Pressure Transducers	Lifetime extensions are required. Additional development for fluorine compatibility is considered required.
Check Valves	Lifetime extensions are required for hydrogen check valves. Fluorine compatible check valves development is necessary.
Propellant Utilization	Vehicles would benefit from improved accuracies.
Attitude Control Thrusters	Thrusters with extended lifetimes are required. Thrusters must be developed for the Integrated LF_2/LH_2 Attitude Control Subsystems.
Integrated Attitude Attitude Control System	Components comprising these systems will require extended lifetimes over existing candidate equivalents.

6.2.1.3 (C) Storable Spacecraft (N_2O_4/50-50). Since there are several large storable propellant vehicles in use at this time (Agena, Titan, Apollo Service Module, Apollo Lunar Module), there exist a number of storable components which were examined in this study. Many of the existing components are applicable to the subsystems.

(U) The results of the examination of the Storable Spacecraft components are presented in Tables 6-15 and 6-16. The generalized conclusions regarding these examinations are presented in Table 6-17. It is interesting to note that there has been a definite trend in the design of storable propellant valves to use ball valve designs. These provide excellent leakage characteristics, but tend to have short lifetimes. Some advancements have been introduced recently in employing movable seats to reduce wear.

6.2.1.4 (U) General Discussions. In the examination of the large number of components considered in this study, it was generally concluded that workable reusable systems can be designed and successfully employed using existing components. The lifetime and reliability characteristics inherent in these components will provide suitable components for the development phases of reusable vehicles, during which time detailed improvements in design can be effected. In most cases, the adaptation of relatively minor changes, such as seals or actuators, will result in suitable components. Aerospace components are of generally high quality.

(U) It was determined that most of the problems which will arise from the use of the components will be principally the result of contamination, corrosion, and poor installations, both mechanically and electrically.

(U) Contamination: The contamination problems in reusable vehicles will require the development and application of "foolproof" methods, inherent in the designs. The most important consideration in propellant subsystems/will be to assure that positive pressures are maintained in the systems, whenever possible, to prevent the entrance of contaminants. Propellant specifications and loading procedures must be rigidly examined. It is doubtful that contamination requirements can be lessened in future reusable vehicles because of the low leakage requirements for some of the subsystems. Also, increasing contamination allowables will increase maintenance.

CONFIDENTIAL

Table 6-15

STORABLE SPACECRAFT (N_2O_4/50-50) PROP
COMPONENT EXAMINATION

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		En
			Gas	Liquid	M-III	M-V	
Propulsion Subsystem	N_2O_4 Pre-valve (U131)	2-1/2	<5	None	30	10	GN_2 400
	50-50 Pre-valve (U132)	2-1/2	<1	None	30	10	GN_2 400
	N_2O_4 Fill and Drain SOV (U133)	1-1/2	<5	None	30	10	GN_2 400
	50-50 Fill and Drain Valve (U134)	1-1/2	<1	None	30	10	GN_2 400
	N_2O_4 Vent and Relief Valve Main Tank Vent (U135)	1	<5	None	30	10	GN_2 400
	50-50 Vent and Relief Main Tank Vent (U136)	1	<1	None	30	10	GN_2 400
	GHe Pressurization Fill SOV (U137)	1/4	<1	NA	30	10	GHe 400
	GHe Pressurization Valve (U138)	1/2	<1	NA	30	10	GHe 400

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-60, Figure 3-21.

1

Table 6-15

O4/50-50) PROPULSION SUBSYSTEMS
EXAMINATION (C)

NFIDENTIAL)

ge	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
uid	M-III	M-V						
ne	30	10	GN_2, N_2O_4 400 to 580°R	U131-1	Ball, 2-1/2-inch Soft Seats 3.3 sccm	Reusable	None	(1) Appears suitable (2) May have low cycle life
ne	30	10	GN_2, 50-50 400 to 580°R	U132	Same as N_2O_4 Pre-valve (U131)			Same as N_2O_4 prevalve (U131)
ne	30	10	GN_2, N_2O_4 400 to 580°R	U133-1	Teflon Seals Cres Cartridge Seal, 1-1/2-inch 1/7 sccm			(1) Same as U131 (2) Appears suitable (3) Low leakage
ne	30	10	GN_2, 50-50 400 to 580°R	U134	Same as N_2O_4 Fill and Drain Valve (U133)			Same as U133
ne	30	10	GN_2, N_2O_4 400 to 580°R	U135-1	Poppet Soft Seat Spring Reference Earth Storable Relief Valve, 5/8-inch	Modification Required	Major	(1) Integral filter (2) Light weight (3) Considerably reduced relief (4) Low flow capacity (5) Does not have command open capability
ne	30	10	GN_2, 50-50 400 to 580°R	U136	Same as N_2O_4 Vent and Relief Valve (U135)			Same as U135
\	30	10	GHe 400 to 580°R	U137	Same as GHe Pneumatic Fill Valve (U82) Table 6-9			Same as U82 except (1) No temp problems (2) Appears suitable
\	30	10	GHe 400 to 580°R	U138-1	Same as U84 Table 6-9			Same as U84 except (1) High flow capacity (2) No temp problems

gure 3-21.

2

Table 6-15 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-III	M-V	
Propulsion Subsystem (cont.)	GHe Pressurization Valve (cont.) (U138)						
	GHe Pressurization Relief Valve (U139)	1/4	NA	NA	30	10	GHe 400 to 5
	GHe Pneumatic Fill SOV (U140)	1/4	<1	NA	30	10	GHe 400 to 5
	GHe Pneumatic Relief Valve (U141)	1/4	NA	NA	30	10	GHe 400 to 5
	GHe Pneumatic SOV Controls flow to pneumatic components and reduces leakage between periods of use (U142)	3/8	<1	NA	30	10	GHe 400 to 5
	N_2O_4 Vent Disconnect (QD131)	1	<20 Ext.	NA	30	10	GN_2, N_2 400 to 5
	50-50 Vent Disconnect (QD132)	1	<20 Ext.	NA	30	10	GN_2, 50 400 to 5

1

ble 6-15 (Cont.)
ONFIDENTIAL)

e	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
d	M-III	M-V						
				U138-2	Piloted Poppet Metal, Metal Seat 3/8-inch	Reusable	None	Same as U84 excepting: (1) High flow capacity (2) No temp problem (3) Appears suitable
	30	10	GHe 400 to 580^{o}R	U139-1	Same as U86-1			Same as U86-1 Appears suitable
				U139-2	Same as U86-2			Same as U86-2
	30	10	GHe 400 to 580^{o}R	U140	Same as GHe Fill Valve (U137)			Same as U137 Appears suitable
	30	10	GHe 400 to 580^{o}R	U141	Same as GHe Pressurization Relief Valve (U139)			Same as U139
	30	10	GHe 400 to 580^{o}R	U142	Same as GHe Fill Valve (U137)			Same as U137 Appears suitable
	30	10	GN_2, N_2O_4 400 to 580^{o}R	QD131	Checking Quick Disconnect, 1-inch	Reusable	None	(1) Light weight (2) High pressure capability (3) May remove Check Valve (4) Appears suitable
	30	10	GN_2, 50-50 400 to 580^{o}R	QD132	Same as N_2O_4 Vent Disconnect (QD131)			Same as QD131 Appears suitable

2

CONFIDENTIAL

Table 6-15 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Enviro
			Gas	Liquid	M-III	M-V	
Propulsion Subsystem (cont.)	N_2O_4 Fill Disconnect (QD133)	1-1/2	20 Ext.	NA	30	10	GN_2, N_2 400 to 58
	50-50 Fill Disconnect (QD134)	1-1/2	20 Ext.	NA	30	10	GN_2, 50- 400 to 58
	GHe Fill Disconnect (QD135)	1/4	NA	NA	30	10	GHe 400 to 58
	GHe Pneumatic Fill Disconnect (QD136)	1/4	NA	NA	30	10	GHe 400 to 58
	Fuel Pressurization Isolation Check Valve. Prevents vapors from diffusing into pressurization line (CK131)	1/2	<1	NA	30	10	GN_2, 50- 400 to 58
	N_2O_4 Pressurization Isolation Check Valve. Prevents vapors from diffusing into pressurization line (CK132)	1/2	<1	NA	30	10	GN_2, N_2 400 to 58
	GHe/50-50 Pressurization Regulator. Main tank regulator. (RG131)	1/2	<1	NA	30	10	GN_2, 50- 400 to 58

1

ble 6-15 (Cont.)

ONFIDENTIAL)

e d	Probable Life (flts) M-III	Probable Life (flts) M-V	Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
	30	10	GN_2, N_2O_4 400 to 580°R	QD133-1		Reusable	None	
	30	10	GN_2, 50-50 400 to 580°R	QD134	Same as N_2O_4 Fill Disconnect (QD133)			Same as QD133
	30	10	GHe 400 to 580°R	QD135				
	30	10	GHe 400 to 580°R	QD136	Same as GHe Fill Disconnect (QD135)			Same as QD135
	30	10	GN_2, 50-50 400 to 580°R	CK131-1	Same as CK101			(1) Same as (CK101), Table 6-7 (2) Appears suitable
				CK131-2	Poppet, GN_2 Check Valve	Reusable	None	(1) Low leakage (2) Susceptible to contamination (3) Appears suitable
	30	10	GN_2, N_2O_4 400 to 580°R	CK132	Same as GHe Check Valve (CK131)			Same as CK131
	30	10	GN_2, 50-50 400 to 580°R	RG131-1	Lapped Metal Seat, Welded Construction Dual Parallel Redundant 1 inch	Modification Required	Minor	(1) Welded static seals (2) Parallel redundant if desired (3) No sliding seals (4) Long life expected (5) Integral filter (6) Less susceptible to contamination (7) Marginal flow capacity (8) Reduce regulator setting

2

Table 6-15 (Cont.)
(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envir
			Gas	Liquid	M-III	M-V	
Propulsion Subsystem (cont.)	GHe/50-50 Pressurization Regulator. Main tank regulator. (cont.)						
	He/N_2O_4 Pressurization Regulator. Main tank regulator. (RG132)		<1	NA	30	10	GN_2, G N_2O_4 400 to
	GHe Pneumatic Supply Regulator (RG133)	3/8	<1	NA	30	10	GHe 400 to

1

6-15 (Cont.)

FIDENTIAL)

Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
M-III	M-V						
			RG131-2	Hard Seat, Dual Series Redundant 3/8 inch	Reusable	None	(1) Simple operation (2) Series redundant available (3) Low weight (4) Low leakage (5) Low flow capacity (6) Susceptible to contaminant
			RG131-3	Metal to Metal Seat, Shutoff Capability Integral pilot solenoid 3/4 inch	Modification Required	Minor	(1) High flow capacity (2) Low leakage (3) May produce significant contaminant (4) May wear excessively (5) Reduce pressure setting
30	10	GN_2, GHe, N_2O_4 400 to 580°R	RG132	Same as GHe/50-50 Pressurization Regulator RG131			Same as RG131
30	10	GHe 400 to 580°R	RG133	Same as GHe Pneumatic Supply Regulator (RG85)			Same as RG85 except no temperature modifications

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 6-16

STORABLE SPACECRAFT (N_2O_4/50-50) INTEGRATE
SUBSYSTEM COMPONENT EXAMINAT

(CONFIDENTIAL)

Subsystem	Component	Required Size (in.)	Allowable Leakage (sccm)		Probable Life (flts)		Envi
			Gas	Liquid	M-III	M-V	
Integrated Attitude Control Subsystem N_2O_4/50-50 FDL-5	N_2O_4 and A-50 Isolation Valves (U501, 502, 506, 507)	1/4			30	10	GN_2, I 400 to
	Pressurization SOV (U503)	1/8			30	10	GHe 400 to
	GHe Pneumatic Supply Relief Valve Prevents overpressure of pumps (U504)	1/8			30	10	GHe 400 to
	GHe Directional Valve Controls pump actuation (U505)	1/8			30	10	GHe 400 to
	N_2O_4 and A-50 Pump Check Valves Fluid directional control valves (CK501, 502, 503, 504 506, 507, 508, 509)	1/4			30	10	GHe 400 to

NOTE: The schematic containing these components is presented in Volumn IIA, Page 3-61, Figure 3-22.

Table 6-16

0-50) INTEGRATED ATTITUDE CONTROL
ONENT EXAMINATION (C)

ONFIDENTIAL)

ge	Probable Life (flts)		Environment	Component Number	Available Components	Reusability Classification	Extent of Modifications	Comments
ld	M-III	M-V						
	30	10	GN_2, N_2O_4 400 to 580°R	U501 U502 U506 U507	Same as N_2O_4 Prevalve (U310)			(1) Same as U310 (2) Appears suitable
	30	10	GHe 400 to 580°R	U503	Same as GHe pressurant SOV (U303)			(1) Same as U303 (2) Appears suitable
	30	10	GHe 400 to 580°R	U504	Same as MMH Tank Relief Valve (U305)			(1) Same as U305 (2) Appears suitable
	30	10	GHe 400 to 580°R	U505-1	Two position, 3-way solenoid, pneumatic control pilot, dual shuttle poppet 1/4 inch 10 sccm	Reusable	None	(1) High flow capacity (2) Fast response (3) Low leakage (4) Long life expected (5) Heavier than necessary (6) May repackage (7) Appears suitable
	30	10	GHe 400 to 580°R	CK501-1 CK502-1 CK503-1 CK504-1 CK506-1 CK507-1 CK508-1 CK509-1	Same as CK101			(1) Same as CK101 (2) Appears suitable

gure 3-22.

2

Table 6-17

SUMMARY OF COMPONENT AVAILABILITY
FOR THE STORABLE SPACECRAFT (U)

(CONFIDENTIAL)

Component Class	General Conclusions
Liquid Valves	Suitable components are available with modifications. The ball valves should have movable seats or easily replaced cartridges.
Vent and Relief Valves	Suitable components are available with modifications.
Vent Disconnects	Suitable components are available.
Fill and Drain Disconnects	Suitable components are available.
Regulators	Suitable components are available with modifications. Leakages need improvement.
Pressurization Valves	Suitable components are available with modifications. Lower leakages needed.
Pressure Switches	Suitable components are available.
Pressure Transducers	Suitable components are available.
Check Valves	Suitable components are available with modifications. The leakages are generally too high.
Propellant Utilization	Vehicles would benefit from improved accuracies.
Attitude Control Thrusters	Thrusters with extended lifetimes are required.
Integrated Attitude Control	Liquid pumps and check valves need lifetime extensions.

(U) Surveys and investigations regarding contamination generation and removal have contributed significantly to the technology, but there appears to be a need for additional correlations, possibly with more use of computer data banks. These correlations should point to needs for directly applicable experimental programs.

(U) Corrosion: The prevention of corrosion is directly related to choice of materials and protection from moisture. The subsystems will have to be carefully examined to prevent galvanic couples. The presence of moisture condensation surfaces, particularly in the cryogenic vehicles will require considerable attention to designs which do not allow the collection of moisture. Since the prevention of condensation is impossible on the subsystem exteriors, the designs should be so as to allow the subsystems to dry out readily after landing. As was previously discussed in Section 3, materials such as multilayer insulations (and possibly foam insulations) should be protected by purging during reentry. Miscellaneous fiberglass batting insulations necessary for cryogenic systems should be designed to dry out readily, possibly with the assistance of a dry purge.

(U) Connections: All-welded or brazed systems are considered desirable for the propulsion subsystems. If the subsystems must be opened for maintenance, such as replacement of a component, this results in a potential contamination problem requiring advancements in techniques. Naturally, accesses such as manholes cannot be welded, and existing approaches are possibly satisfactory.

(U) Leakage: Complex plumbing and manifolded fluid systems impose problems in quantitative measurement of leakage in checkout operations. In a reusable system, it is considered desirable to monitor for increased leakage rates between flights in an efficient manner.

(U) Means to monitor component internal leakage quantitatively at the components, while still assuring subsystem integrity relative to moisture and other contamination, is considered to be desirable.

(U) In the examination of the leakage of gases from propellant tanks, one of the more serious leakage problems is the loss of helium, since this involves substantial weight penalties for storage, etc. Also, it has been generally noted that valve leakage is reduced when liquid is in contact with valves instead of gas. If it were possible to maintain liquid propellant in contact with the valve for the majority of the vehicle operating time, then helium could be conserved and total leakage probably reduced. LMSC has devised a concept to accomplish this through the use of surface tension devices. Naturally, it is relatively straightforward to keep the main propellant feed valves covered with liquid propellant through the use of surface tension devices, since this is an acceptable method. However, covering other penetrations, such as vent lines requires special considerations. The use of "galleries" to refill the devices after engine operations is required. Also, consideration must be given to removing the propellant during emergency venting, etc. This concept may be possibly applied to penetrations such as connectors.

(U) <u>Attitude Control Propellant Expulsion:</u> The expulsion of attitude control propellants was given particular attention. The probable design accelerations are:

- Translations (Forward and Deceleration)
  - Reusable Launch Vehicle – 1×10^{-2} g maximum
  - FDL-5 – 1×10^{-2} g maximum
- Reentry Maneuvers
  - Reusable Launch Vehicle – Approx. 0.2 g maximum
  - FDL-5 – Approx. 0.2 g maximum

(U) Experience has shown that stable surface tension devices can be easily designed for accelerations on the order of 1×10^{-2} g. Therefore, the surface tension devices are very attractive candidates for these applications. However, when accelerations are on the order of 0.2 g, the design of surface tension devices becomes more difficult, especially for tanks of several feet in diameter, as required for some of the propellant loading. This presents the possibility that the attitude control propellants could be separated into two tankage systems, the bulk of the propellant oriented by surface tension, and that propellant required for reentry separated into tankage with positive expulsion devices or more complex surface tension devices.

(U) Bladders are normally employed in a collapsing mode, expelling the propellant through a central standpipe. These may also be used in an expanding mode. Bladders are sensitive to boost-phase sloshing and abrasive action of the bladder rubbing on the tank walls. Only two materials are available that will withstand nitrogen tetroxide immersion for more than 4 days – Teflon and carboxy nitroso rubber. Unfortunately, both materials are very permeable to the propellant. The swelling phenomenon may be the principal reason for the failure of metallic plating on Teflon to act as a permeation barrier. "Aluminized" bladders have been found to somewhat decrease the permeability.

(U) Both Teflon TFE and FEP can be used. The TFE is stronger and has a higher flex life and lower modulus than FEP. The FEP has a lower permeability. Examination of the studies from a number of sources indicate that a cycle life of 10 cycles would be the maximum attainable. The exposure lifetime of bladders would probably be limited to approximately 30 to 60 days. Compound A is a severe oxidizer and, as in the case of nitrogen tetroxide, it is doubtful that a suitable bladder can be developed. The probability of success of a bladder for use with hydrazine fuels is more promising. While Teflon is satisfactory for this application, ethylene propylene rubber (EPR) is available. Glass fabric reinforcement may be employed in larger sizes.

(U) It is expected that a bladder can have a lifetime of some 100 cycles, which may be satisfactory for some of the mission applications.

(U) Diaphragms or membranes may be polymeric or metallic. The polymeric diaphragm approach is subject to the conditions discussed for complete bladders. Recent developments in metallic bladders have been successful in developing bladders that may be capable of over 10 cycles. These are made of 321 stainless steel with 308 wire and copper brazed joints.

(U) Metallic bellows present more promise for multiple use than bladders or diaphragms. Tests indicate that the number of cycles which the bellows are capable of performing is a function of the ratio of the expanded to non-expanded length. If the expanded to non-expanded length is kept low, the expulsion cycles can possibly be extended to several hundred cycles.

6.3 ACCESSIBILITY STUDIES (U)

(U) It was the purpose of the accessibility studies to determine those components which would probably require replacement in reusable subsystems in order to determine which should be accessible for maintenance. The results of the investigations were also beneficial to the examination of components in paragraph 6.2 and the subsystem tradeoff studies in Section 7. The accomplishment of these studies was possible through the use of a computer program, formulated after the approaches being used for forecasting commercial airplane maintenance requirements.

6.3.1 Predictability Approach (U)

(U) The term "predictability" as employed in the study relates to the probability that a subsystem or component will conform to requirements over a given period of time. This term is used to indicate not only "reliability," but also the effects of replacement of components as a result of "wearout."

(U) There exist two probabilities of failure that are considerations in reusable systems:

- The probability of failure per flight, which is a constant for all flights, if constant failure rates for the components may be assumed. This is essentially a function of the effective redundancies in the subsystems and, of course, the failure rates of the components.
- The probability of failure in "N" number of flights, which does not relate to the probability of failure per flight, but is an excellent indicator for the comparison of reusable subsystems.

(U) This latter probability of failure is affected by the removal of components as these reach their respective lifetimes, and are replaced by "new" components.

(U) The failure rate vs. operating time curve shown in Figure 6-2 provides the basis for reliability and lifetime considerations. In order for constant failure rates to be used, the flat portion of the curve must be the operating range of the component lifetimes. Almost no information exists on the "wearout" region with regard to the failure rates, and the prediction methods are beyond the scope of generally usable methods.

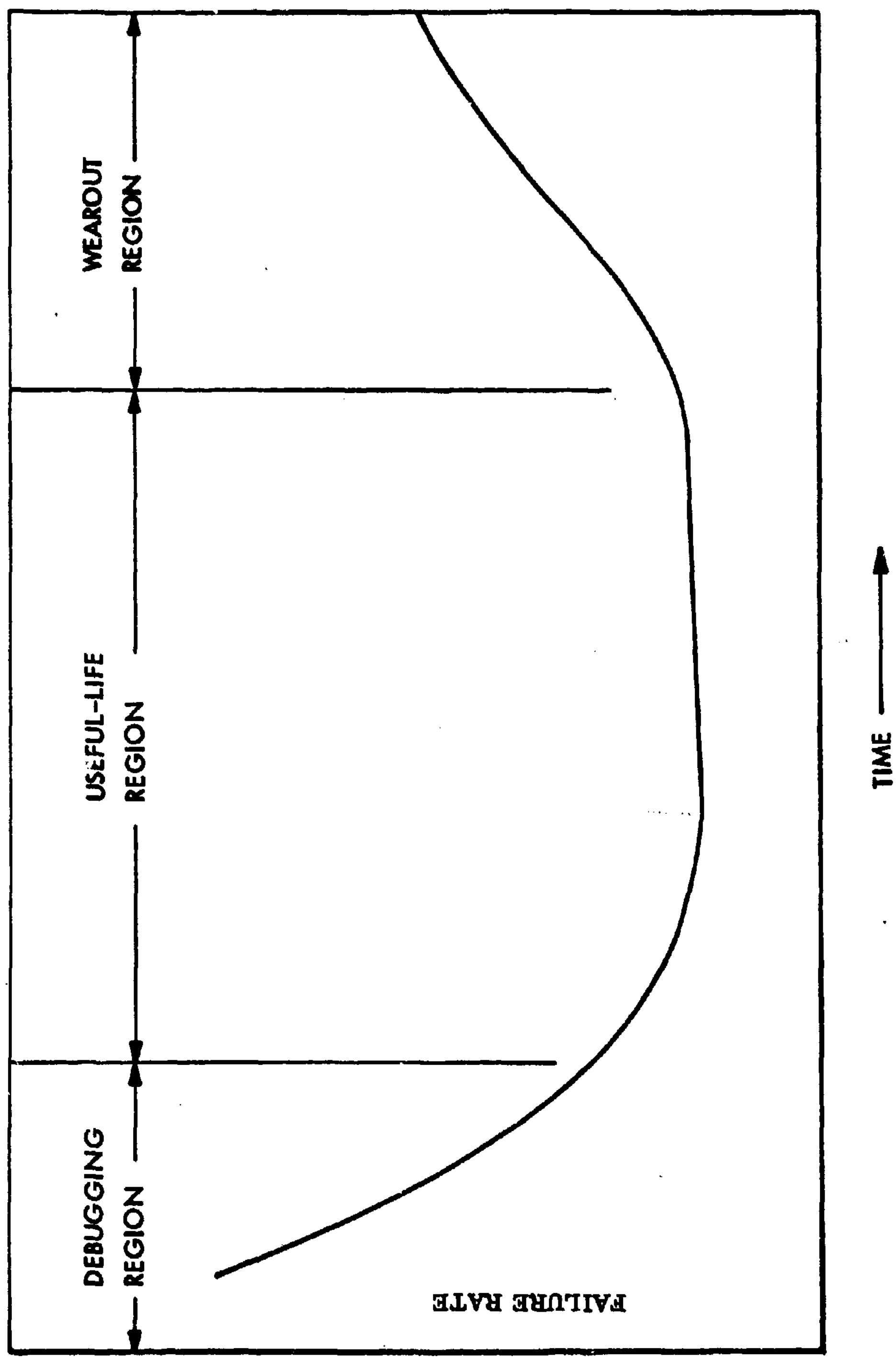


Figure 6-2 Component Lifetime Phases (U)

(U) Therefore, constant failure rates and exponentially distributed failures were accepted after an examination of their applicability. Several investigations have been made regarding this subject, such as that presented in Reference 34.

(U) In order to assure that the components are operating in the effective useful life region, either component lifetime data are required (which are practically non-existent) or the lifetimes must be estimated from known failure rate data (reliability data). If it is assumed that existing failure rate data are reasonably good, an estimate of this minimum wearout-failure-free life can be made for any degree of statistical confidence by utilizing the pure-chance chi-square (χ^2) estimator,

$$M_L = \frac{2M}{\chi^2_{\alpha,2}}$$

where

M_L = the lower limit of the mean wearout distribution (Effective useful life)
M = Mean life to wearout failure (useful life)
χ^2 = the pure-chance chi-square number
Subscript α = 1-desired confidence
Subscript 2 = 2 degrees of freedom associated with zero failures.

(U) The literal interpretation of this estimate (M_L) is: if the mean wearout life is M, as given, one can expect on the basis of pure chance that (1 - α) percent of the time the device will not fail due to wearout in less than hours.

(U) As an example assume that a pressure switch is claimed to have a mean life of 25,000 cycles. On the basis of pure chance and for a risk (α) of 0.05, the lower limit of the wearout distribution can be expected to be:

$$M_L = \frac{2 \times 25{,}000}{\chi^2_{0.05,\,2}} = \frac{50{,}000}{5.99} = 8349 \text{ cycles}$$

(U) That is, there is a 5-percent risk that failures other than those due to wearout will occur over the period of 0 to 8349 cycles. The wearout distribution can now be defined to exist over the range

$$8349 < 25,000 < M_{max}.$$

This implies that the standard distribution might be

$$\sigma = \frac{25,000 - 8349}{3} = \frac{16,651}{3} = 5550 \text{ cycles}$$

The total range might then be construed to be

$$8349 < 25,000 < 41,651 \text{ cycles}$$

(U) From the preceding, the following inferences can be made:

- The exponential or pure-chance probability will only hold for mission requirements of less than 8350 cycles.
- The probability that the device will operate continuously for longer than 41,000 cycles is practically zero.

(U) The validity of the estimated standard deviation, which was obtained by using the chi-square estimator, is established by the following considerations. It is well known that all possible families of distribution are, for all practical purposes, between the exponential and the normal. This is shown by the gamma, beta, chi-square and Weibull families of distribution. In estimation of standard directions therefore, the minimum value is given by the exponential, since σ^2 = mean, then $\sigma = \sqrt{M}$. The maximum σ for the normal distribution of failures occurs when the range is from t = 0 (or cycles = 0) to the mean, i.e., $\sigma = \frac{M}{3}$. From the example above, $\sigma e = \sqrt{25,000} \approx 158$ and the maximum $\sigma_n = \frac{25,000}{3} \approx 8333$. Since the estimate of 5550 is reasonably close to the maximum normal, it may be considered a reasonable estimate.

(U) This approach for estimating component lifetimes was incorporated into the SETA II program described in paragraph 6.3.2, for the purpose of estimating component lifetimes

(U) when these were not available for input to the program. In these investigations, it was assumed that the confidence level should be 0.99.

(U) Examples of the calculated lifetimes derived by this technique were selected at random from the SETA computer outputs as they were being used in subsystem evaluations and presented in Table 6-18. It may be noted that these lifetimes appear to be fairly consistent with the state-of-the-art and supplier's estimates of the lifetimes of their components.

6.3.2 Method of Analysis of Accessibility(U)

(U) The Systems Evaluation and Tradeoff Analysis II (SETA II) computer program was utilized in the accessibility studies. This program has many capabilities and features which were not required for the evaluations. The program is basically a reliability and systems analysis tool. The important features applicable to this study were:

- Capability of predicting first-flight reliabilities and to optimize weight and redundancy.
- Capability of predicting and tabulating for each of the components in one operation the effects on overall system reliability for any number of redundancies in each individual component, and the effects on system weight.
- Determination of the desirable redundancy – active, standby, etc.
- Automatic consideration of the component Effective Useful Life, at any specified confidence limit, and automatic replacement of components about to exceed lifetimes, noting the replacement, and continuing the analysis through the specified number of missions.
- Capability to produce the "Nth" mission printout representing a component, and subsystem flight history of replacement and reusability.

(U) The procedure employed in using this program was as follows:

(1) The subsystems were examined for initial and optimal reliability. This normally resulted in unacceptable numbers of redundancies of lighter weight components. If the results of the analyses were reasonable, it was not necessary to perform step (2), and the redundancies were indicated on the schematics

(2) Since the required optimal redundancies were usually unreasonable, the program was utilized to produce printouts of the effects on overall reliability from different numbers of redundancies in each component. Then, by inspection, it was possible to determine the desired redundancies. These were indicated on the schematics.

Table 6-18

TYPICAL COMPONENT LIFETIME RESULTS (U)
(CONFIDENTIAL)

Subsystem	Component	Calculated Lifetime
Fill, Drain, and Feed	LH_2 SOV	25,000 Cycles
	LO_2 SOV	18,000 Cycles
Vent	LH_2 Vent Assy Reusable Tanks	17,000 Cycles
	LO_2 Vent Assy Reusable Tanks	17,000 Cycles
Pressurization	GH_2 SOV	15,000 Cycles
	GH_2 Regulator	15,000 Hours
	GHe Regulator	20,000 Hours
	GHe Regulator	17,000 Hours
	Check Valves	28,000 Cycles
	LH_2 Pressure Switch	6,500 Cycles
	LO_2 Pressure Switch	13,000 Cycles

(U) (3) With the desired specified redundancies, the first flight probabilities of failure were obtained.

(4) Component lifetime estimates were input where available or, if not, calculated by the program as previously described, and analyses were performed to determine the probability of failure as a function of the "interval" of a number of flights. Component replacements were automatically indicated by the program.

(U) The duty cycles selected for the components were a combination of the required operational cycles and the checkout cycles, as presented in Section 5.

6.3.3 Results of Accessibility Studies (U)

(U) The results of the accessibility studies are presented in the form of curves which indicate the flight at which components must be replaced. The identification of the components is consistent with the schematics presented in Section 3. The general coding is as follows:

CK – Check Valves
DP – Pump
HBX – Heat Exchanger
LGP – Liquid Pump
LLD – Liquid Level Device
PS – Pressure Switch
PT – Pressure Transducer
RG – Regulator
T – Thruster
U – Valves

(U) The curves containing the results are grouped by vehicle and by mission.

Reusable Launch Vehicle:

Mission I – Figures 6-3 through 6-15
Mission II – Figures 6-16 through 6-28

Cryogenic Spacecraft:

Mission III – Figures 6-29 through 6-44
Mission IV – Figures 6-45 through 6-60

Storable Spacecraft:

Mission III – Figures 6-61 through 6-66
Mission IV – Figures 6-67 through 6-76

(C) It may be noted that many of the subsystems appear to be capable of performing the required number of missions. This is subject to many of the factors associated with contamination, corrosion, etc., which were previously discussed. Any component which is indicated on the curves to be subject to replacement should be considered a marginal component, and be given special attention in the designs.

REUSABLE LAUNCH VEHICLE SUBSYSTEMS

RESULTS OF ACCESSIBILITY STUDIES

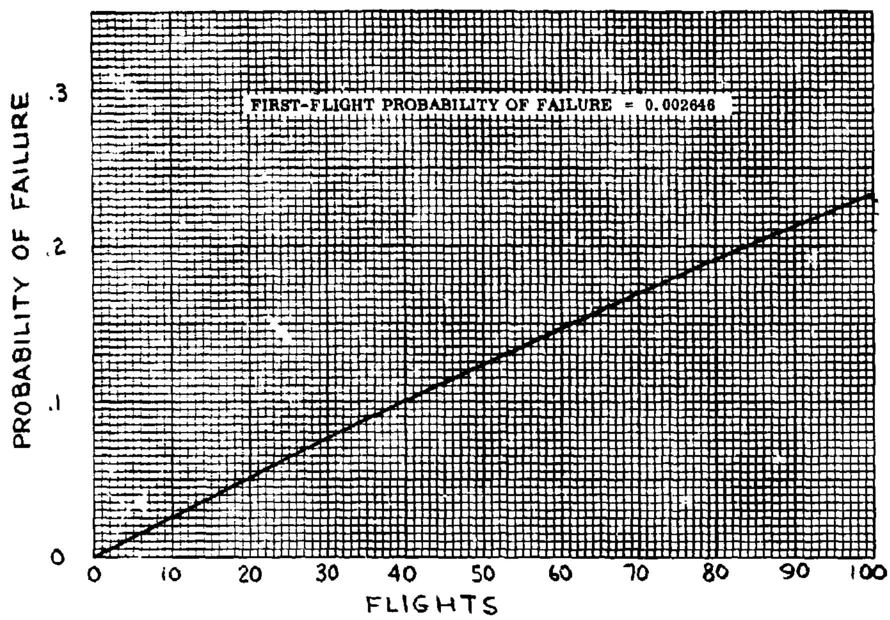


Figure 6-3 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Fill, Drain, and Feed (C)

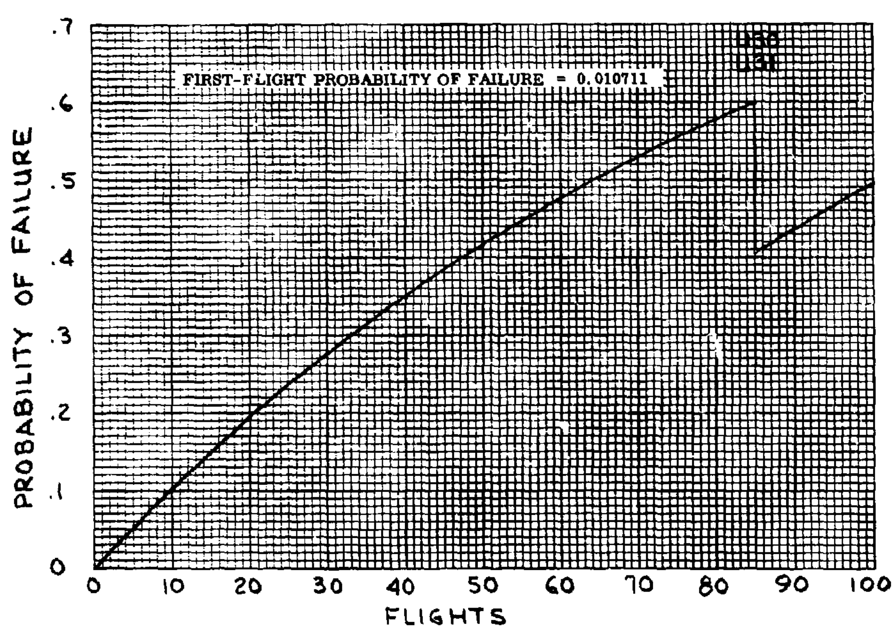


Figure 6-4 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Ground Vent/Emergency Flight Vent (C)

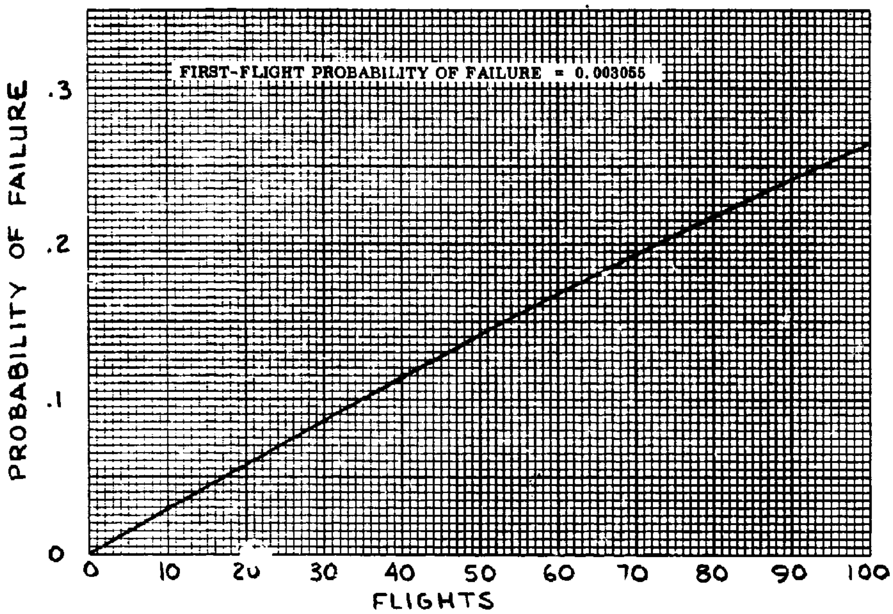


Figure 6-5 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Thermal Conditioning/ Feedline Cooling (C)

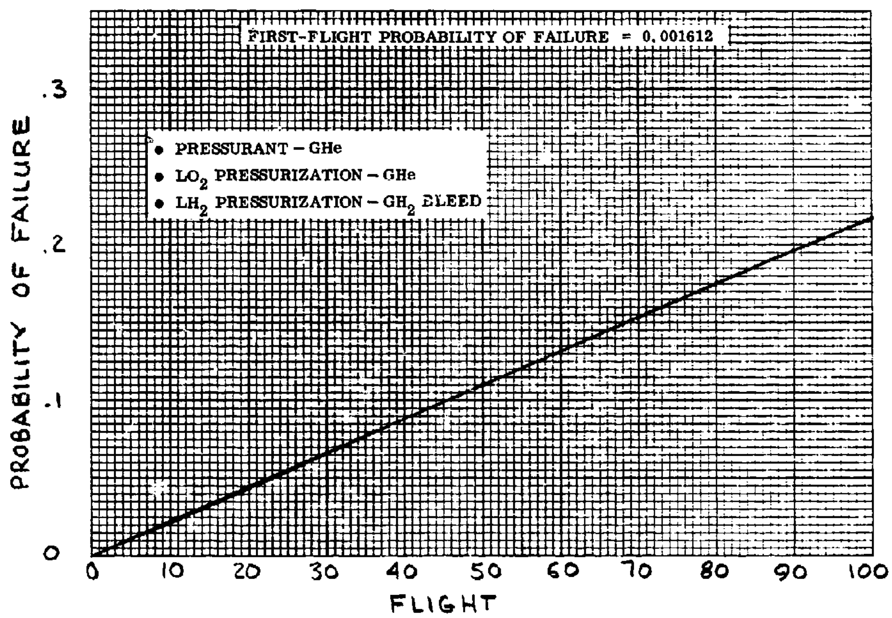


Figure 6-6 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Pressurization, Regulator Controlled (C)

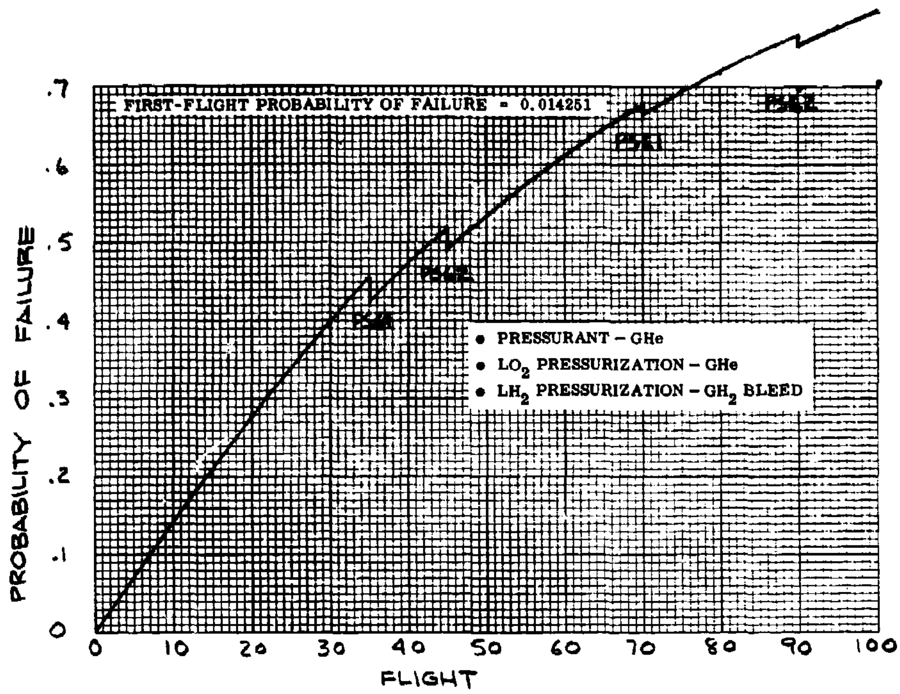


Figure 6-7 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Pressurization, Valve Controlled (C)

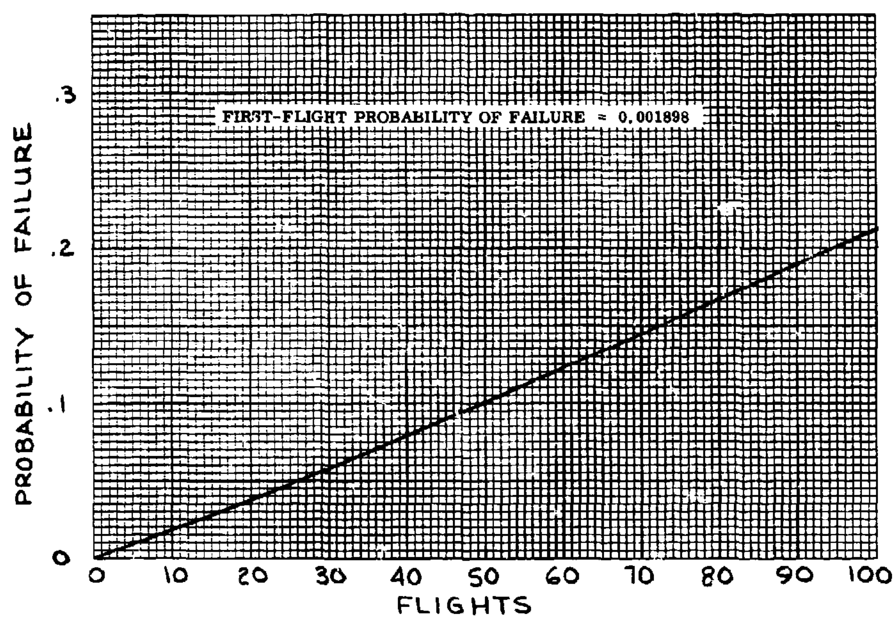


Figure 6-8 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Autogenous Pressurization, Regulator Controlled (C)

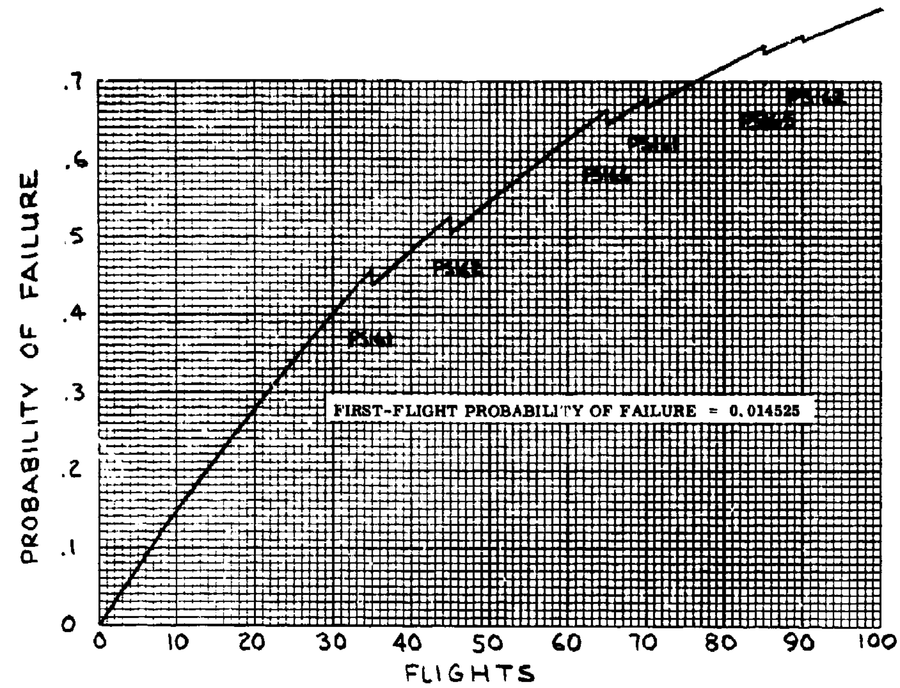


Figure 6-9 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Autogenous Pressurization, Valve Controlled (C)

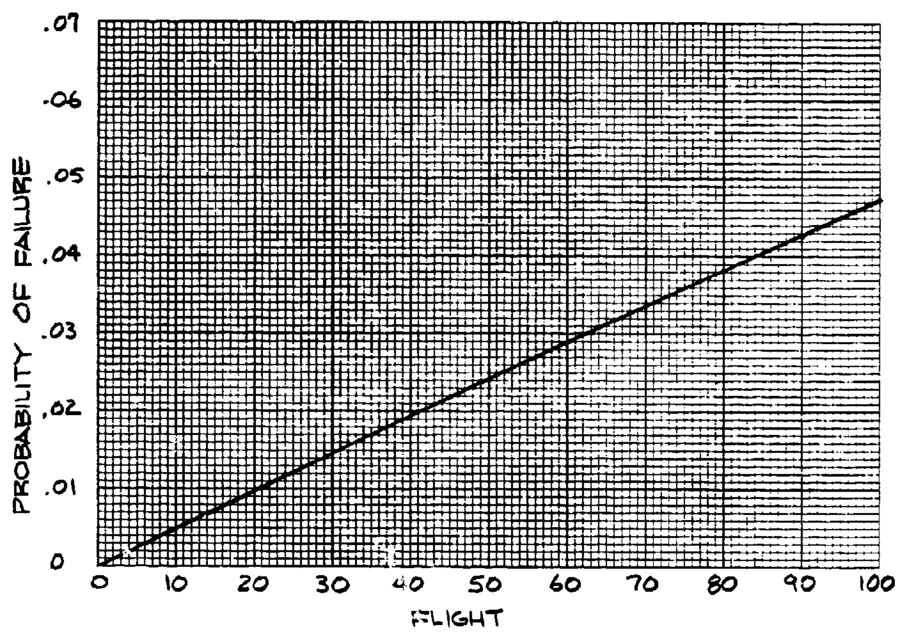


Figure 6-10 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Propellant Utilization, Capacitance Gaging ( ) (C)

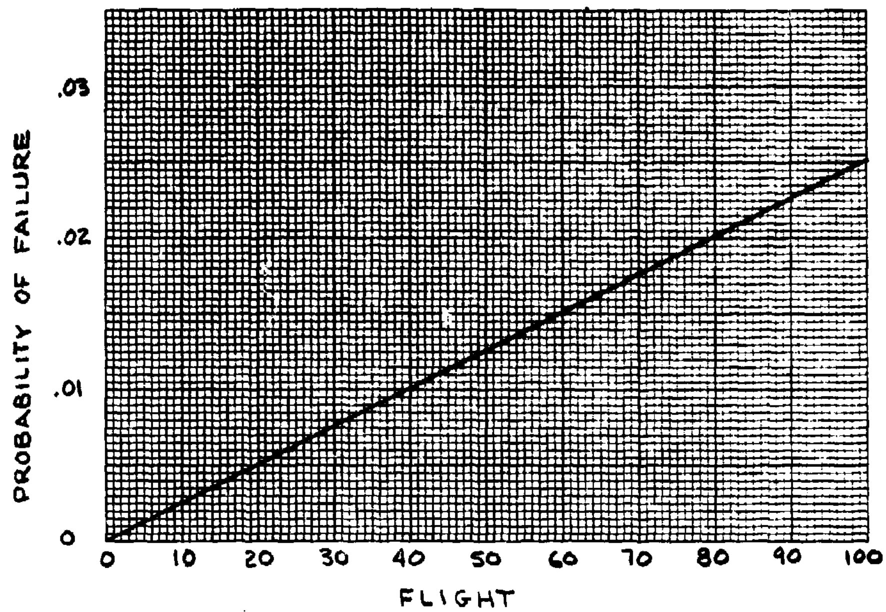


Figure 6-11 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Propellant Utilization, RF Gaging (C)

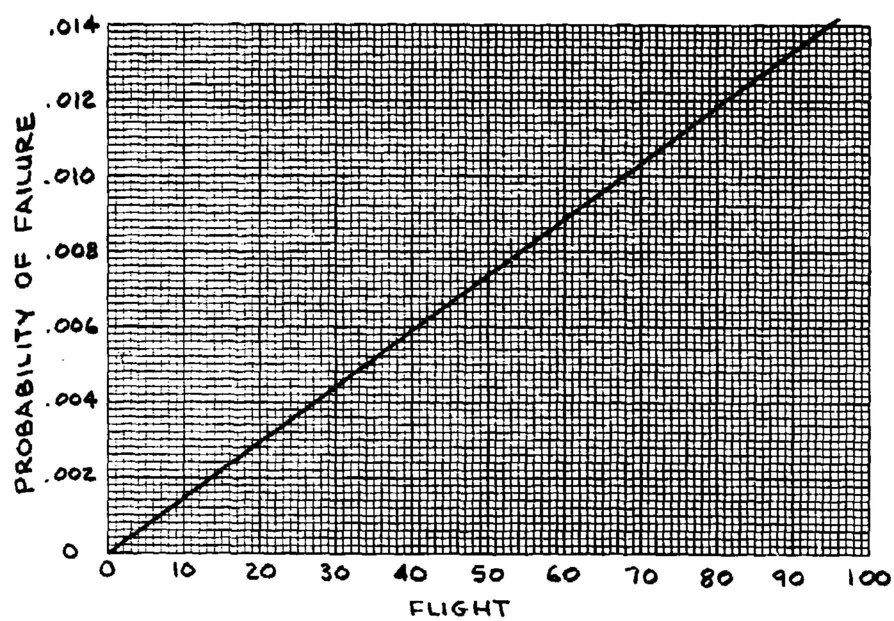


Figure 6-12 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Propellant Utilization, Mass Flow Metering ( ) (C)

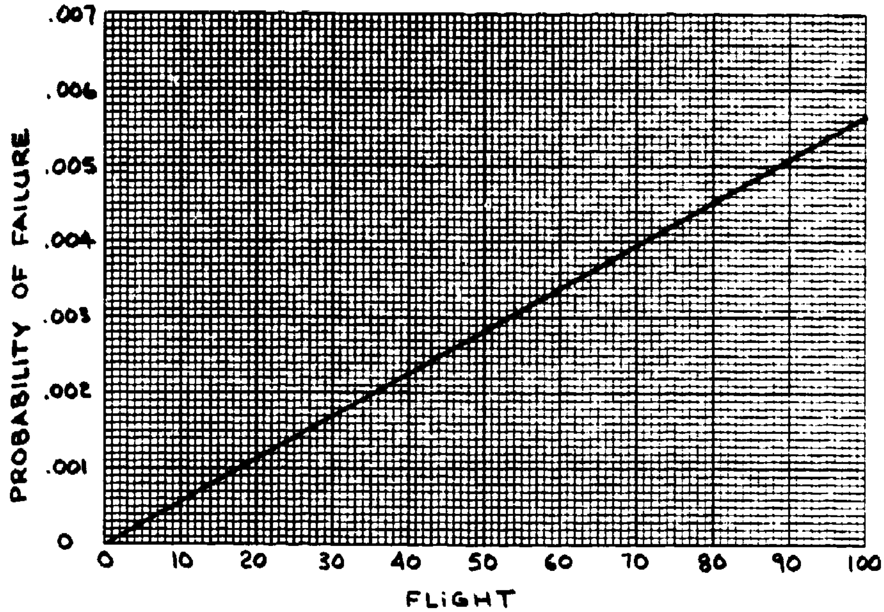


Figure 6-13 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Propellant Utilization, Nucleonic Gaging (C)

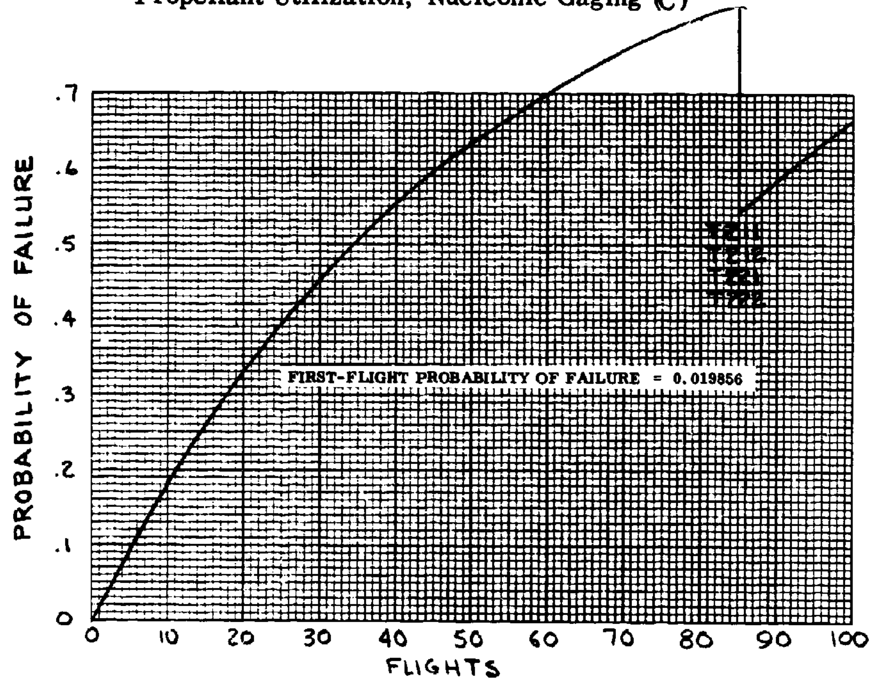


Figure 6-14 Reusable Launch Vehicle (LO_2/LH_2), Mission I, ACS System, Nonintegrated (C)

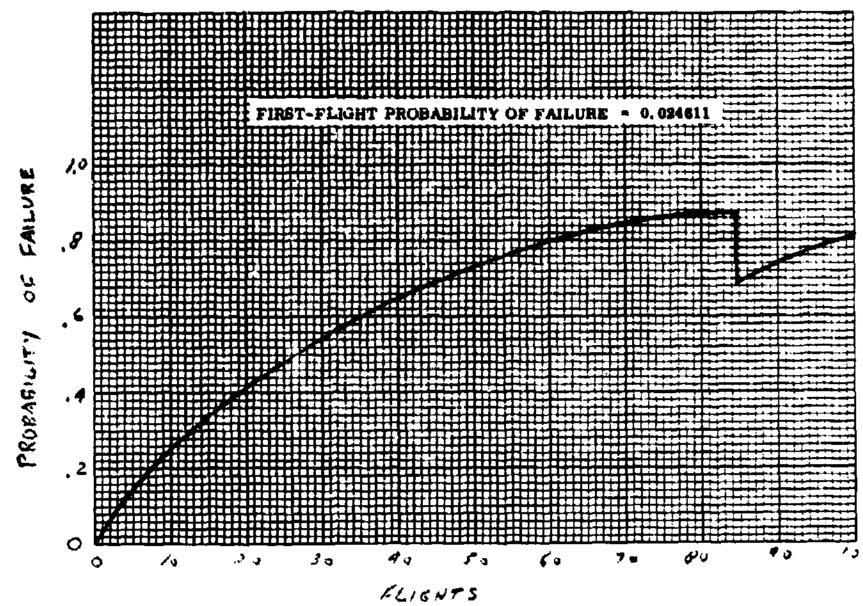


Figure 6-15 Reusable Launch Vehicle (LO_2/LH_2), Mission I, Attitude Control System, Integrated (C)

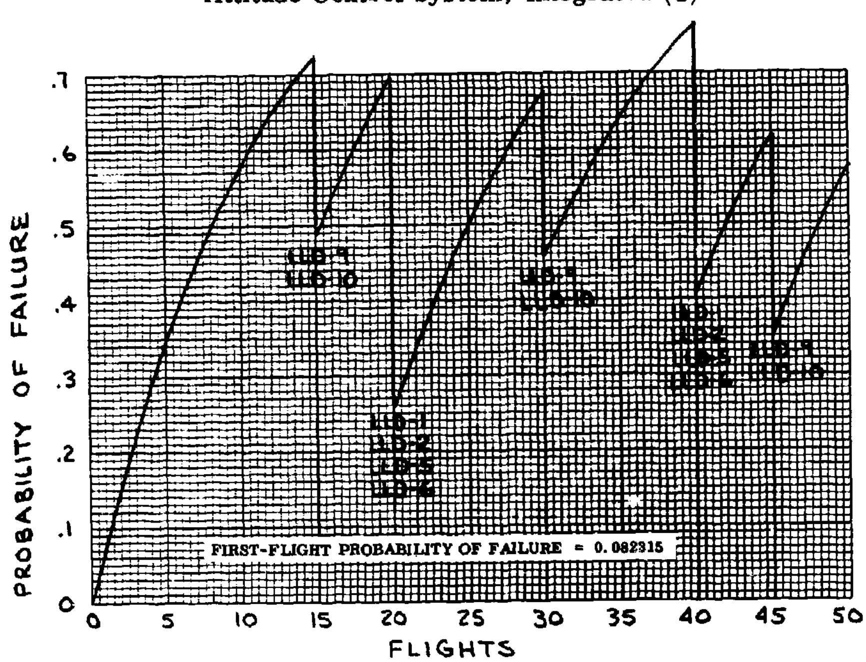


Figure 6-16 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Fill, Drain, and Feed (C)

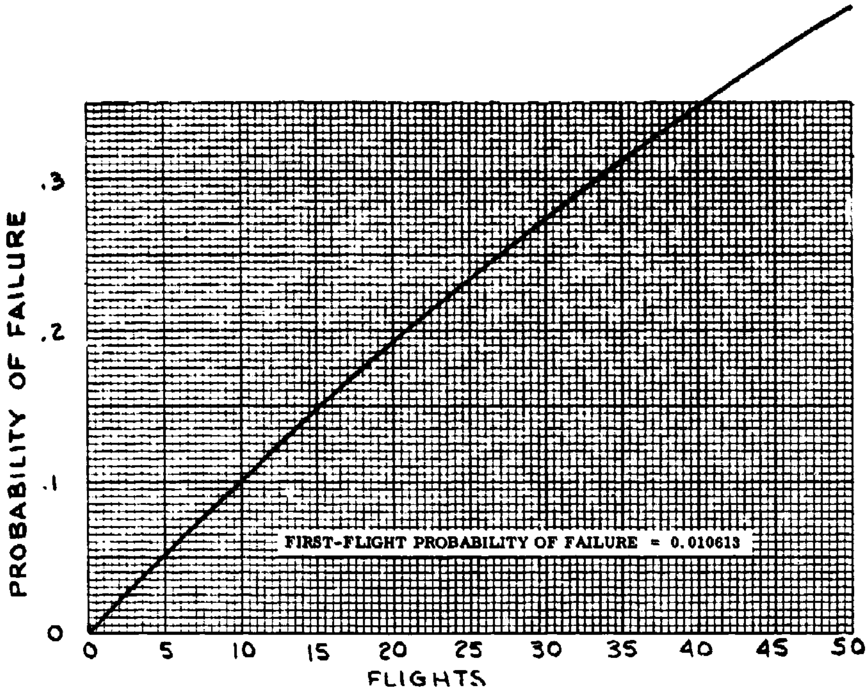


Figure 6-17 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Ground Vent/Emergency Flight Vent (C)

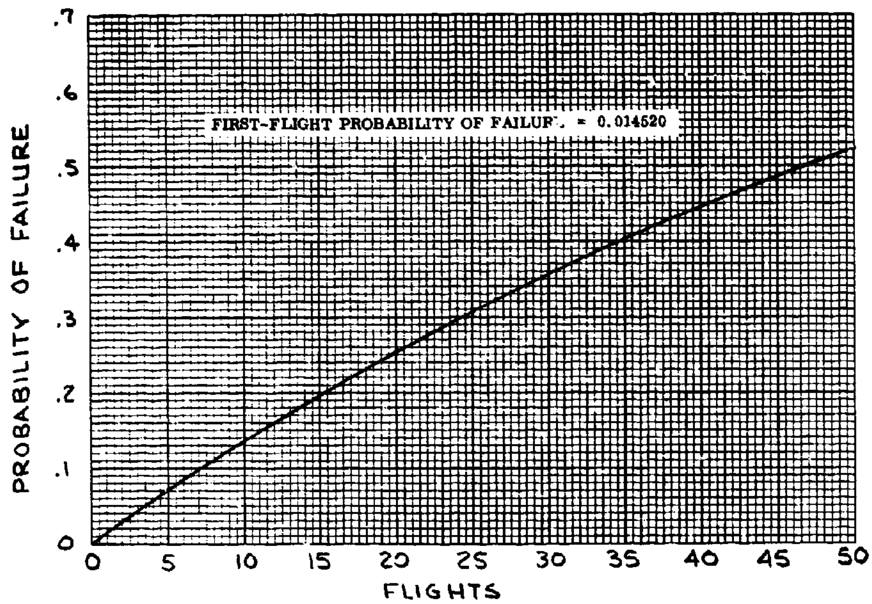


Figure 6-18 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Thermal Conditioning/Feedline Cooling (C)

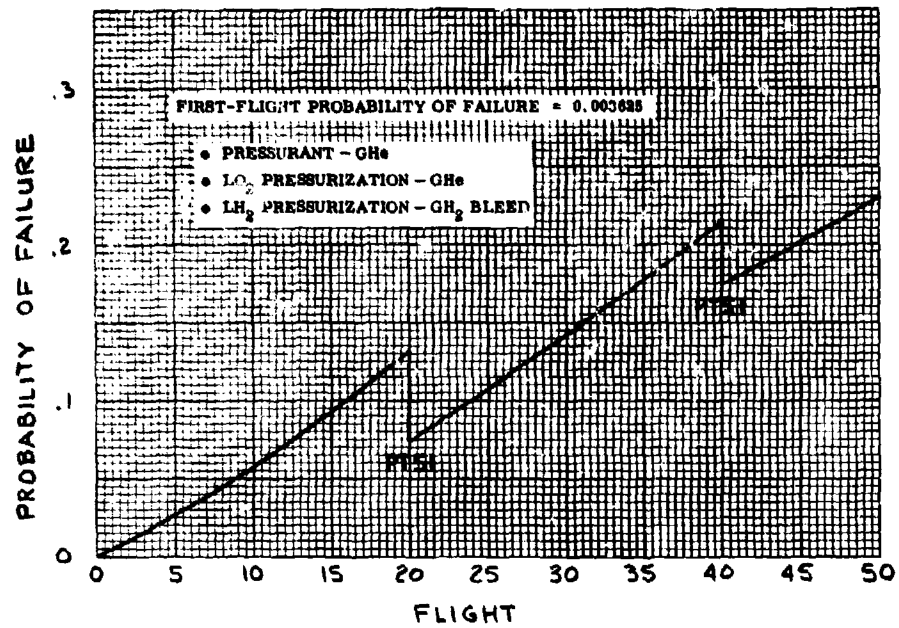


Figure 6-19 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Pressurization, Regulator Controlled (C)

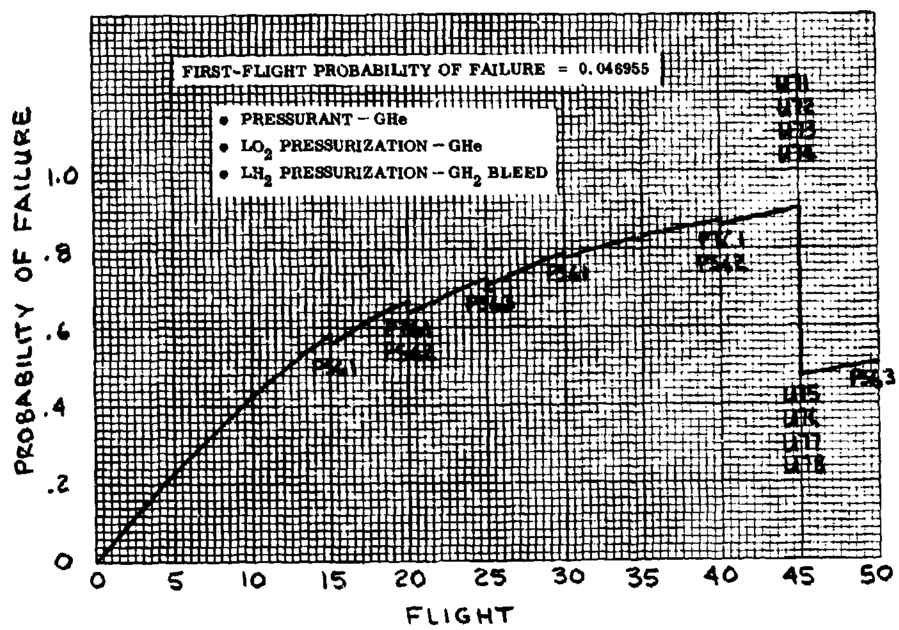


Figure 6-20 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Pressurization, Valve Controlled (C)

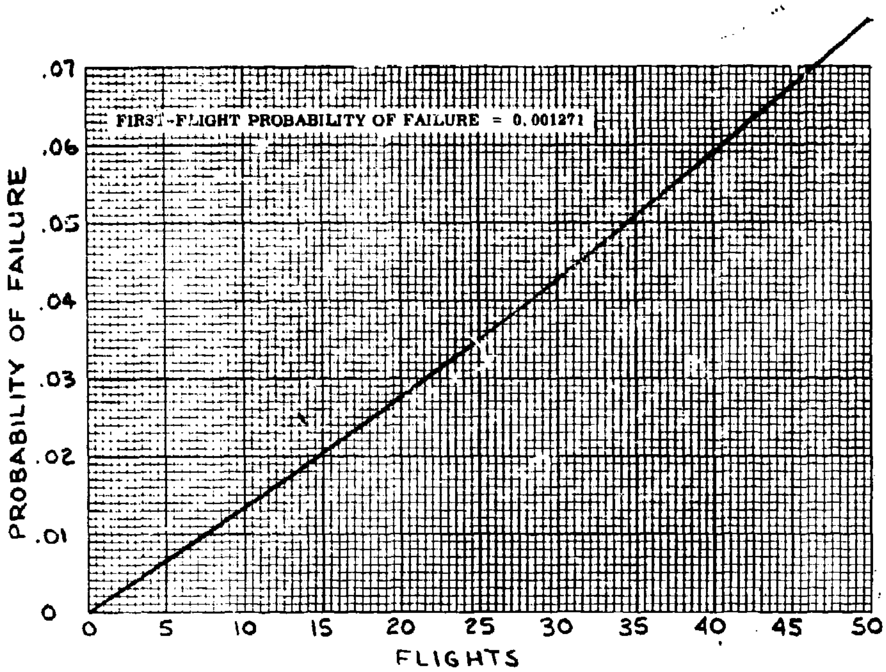


Figure 6-21 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Autogenous Pressurization, Regulator Controlled (C)

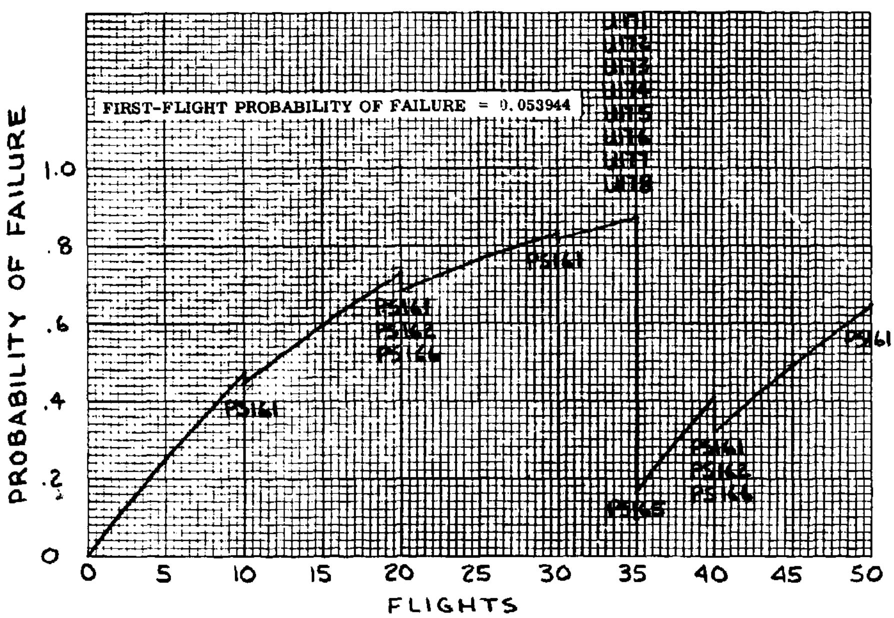


Figure 6-22 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Autogenous Pressurization, Valve Controlled (C)

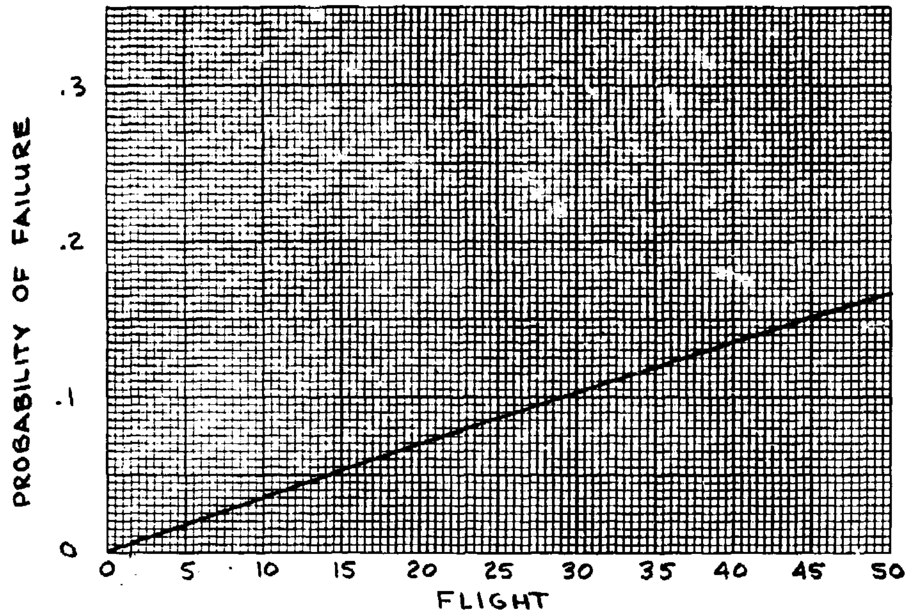


Figure 6-23 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Propellant Utilization, Capacitance Gaging (C)

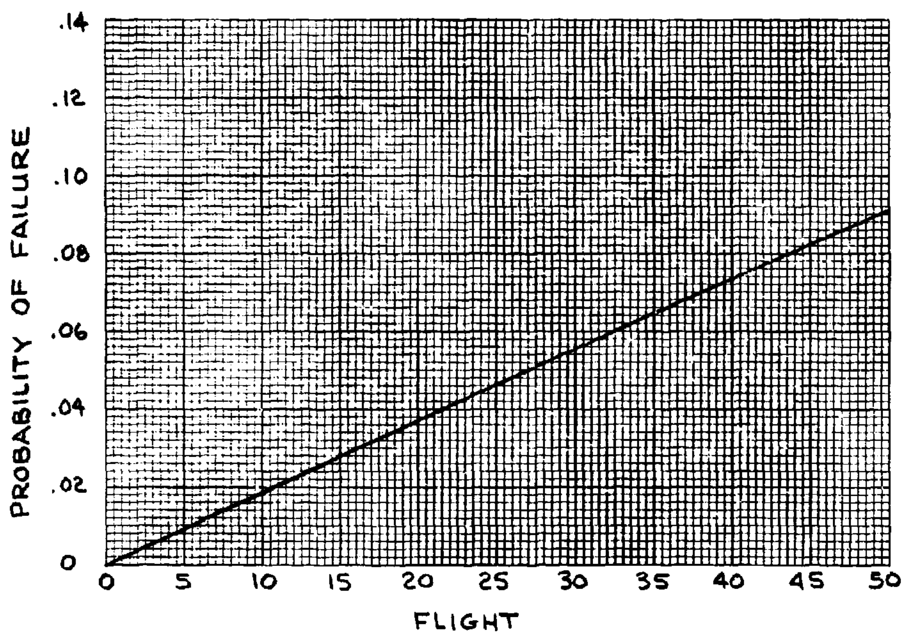


Figure 6-24 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Propellant Utilization, RF Gaging (C)

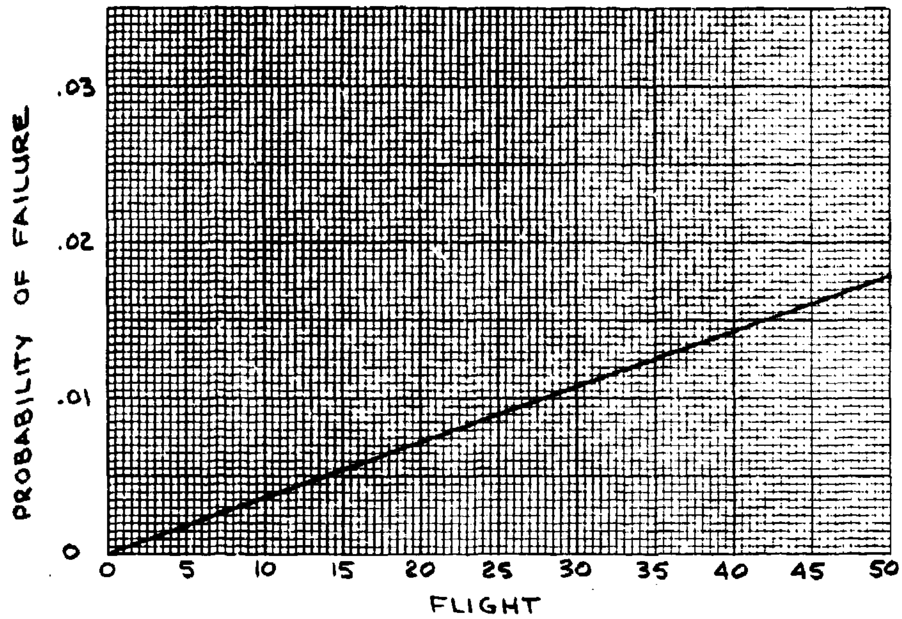


Figure 6-25 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Propellant Utilization, Mass Flow Metering (C)

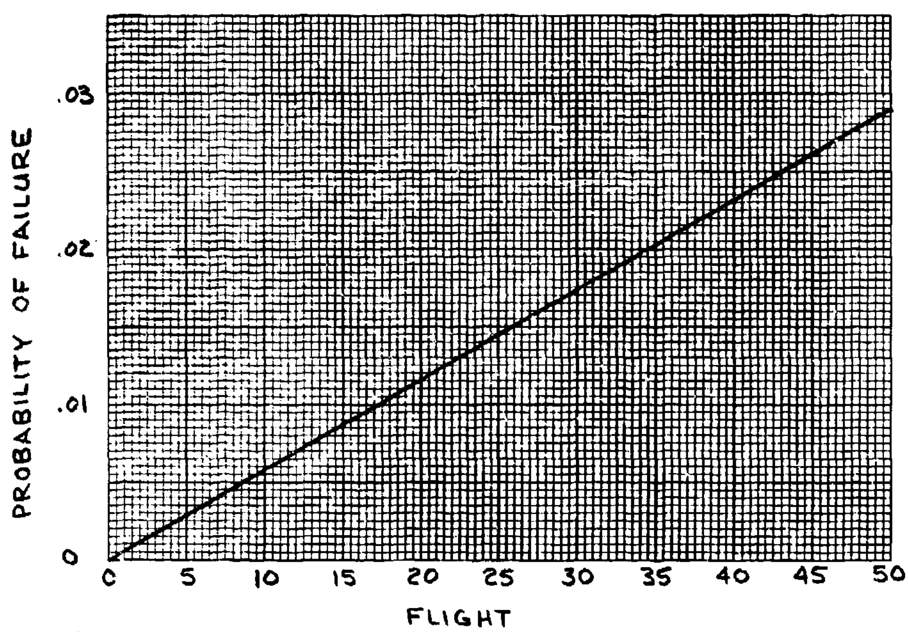


Figure 6-26 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Propellant Utilization, Nucleonic Gaging (C)

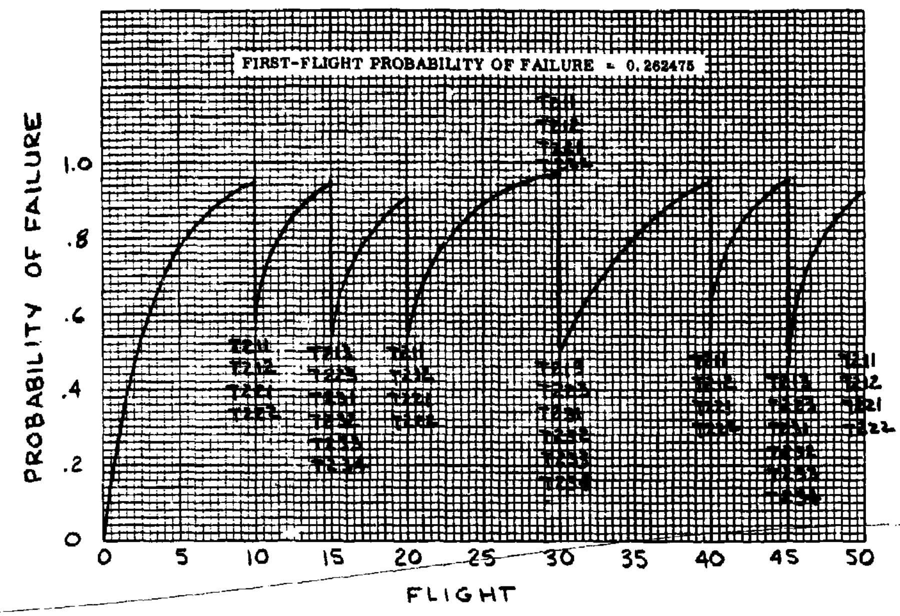


Figure 6-27 Reusable Launch Vehicle (LO_2/LH_2), Mission II, ACS System, Nonintegrated (C)

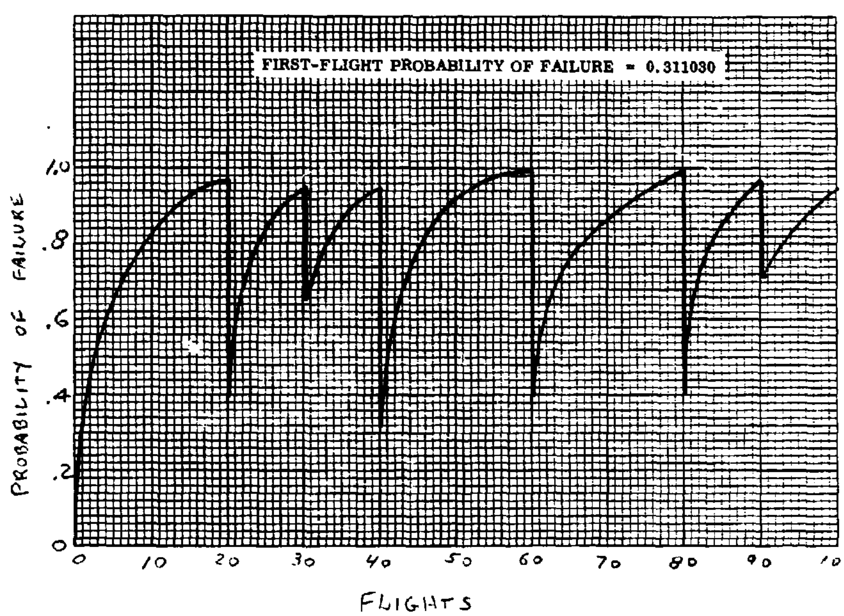


Figure 6-28 Reusable Launch Vehicle (LO_2/LH_2), Mission II, Attitude Control System, Integrated (C)

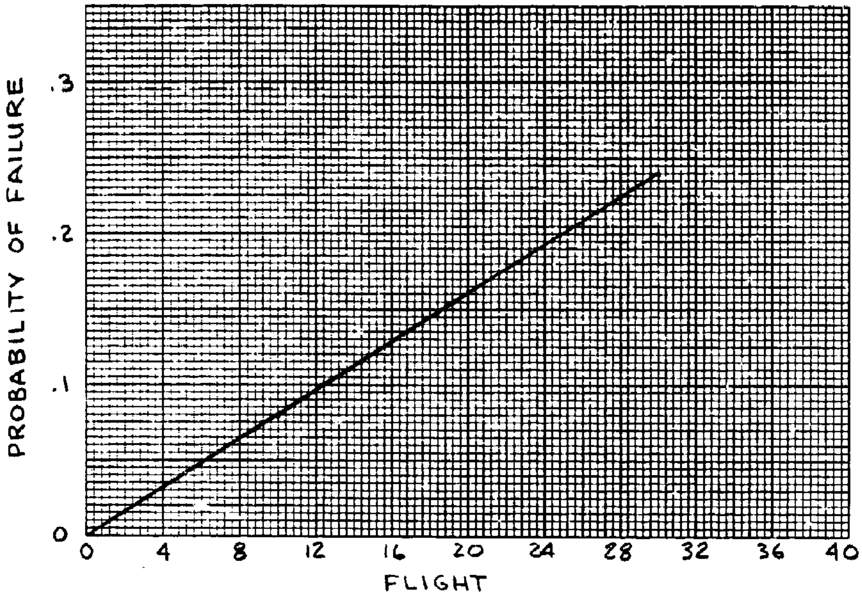


Figure 6-29 Cryogenic Spacecraft (LF_2/LH_2), Mission III, PropulsionSystem, Instant Start (C)

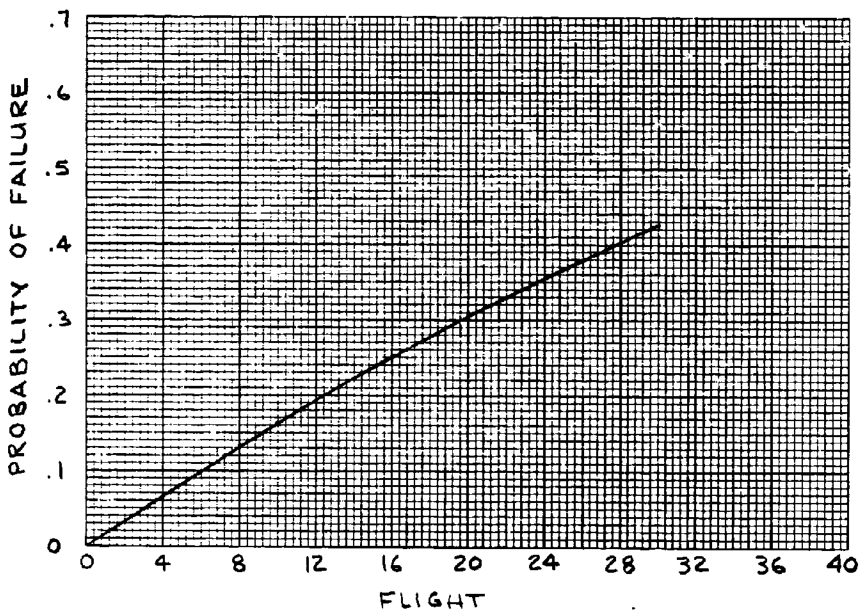


Figure 6-30 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Propulsion System, Normal Start (C)

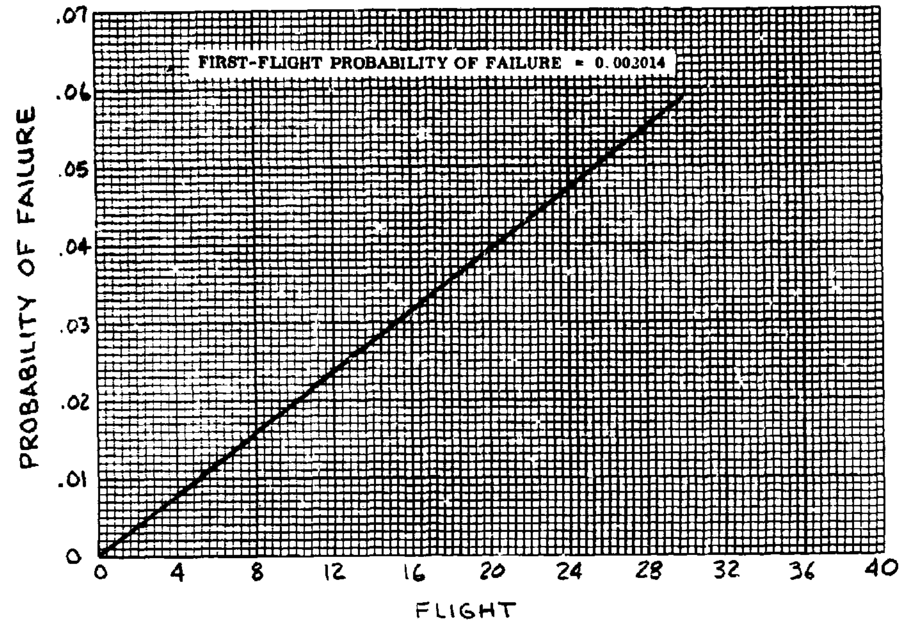


Figure 6-31 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Fill, Drain, and Feed, Instant Start (C)

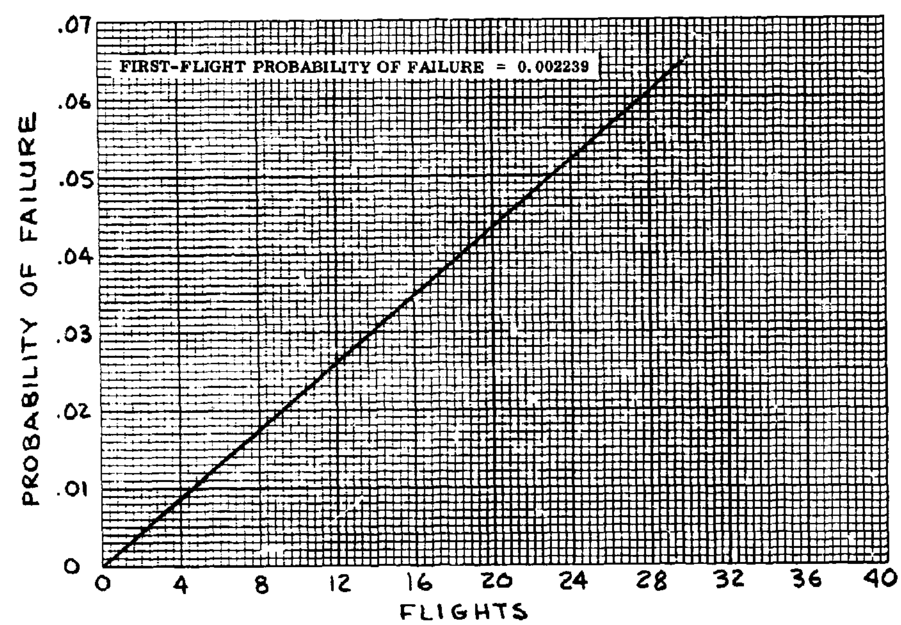


Figure 6-32 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Fill, Drain, and Feed, Normal Start (C)

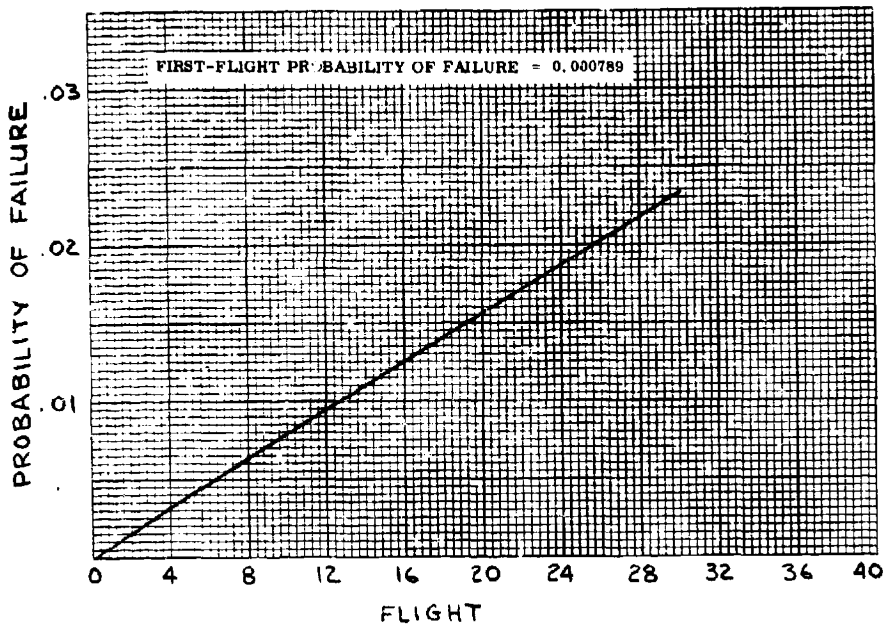


Figure 6-33 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Ground Vent/Emergency Flight Vent, Instant Start (C)

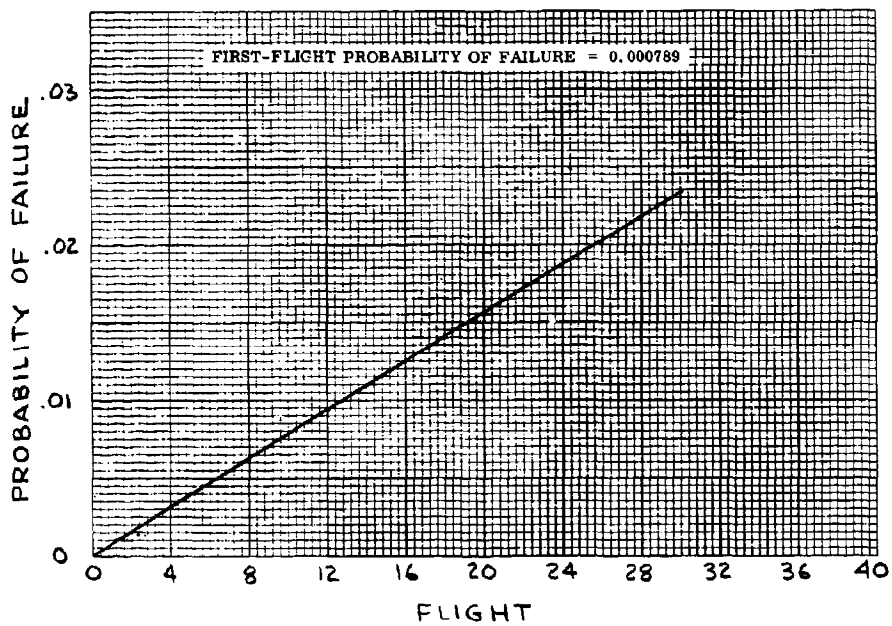


Figure 6-34 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Ground Vent/Emergency Flight Vent, Normal Start (C)

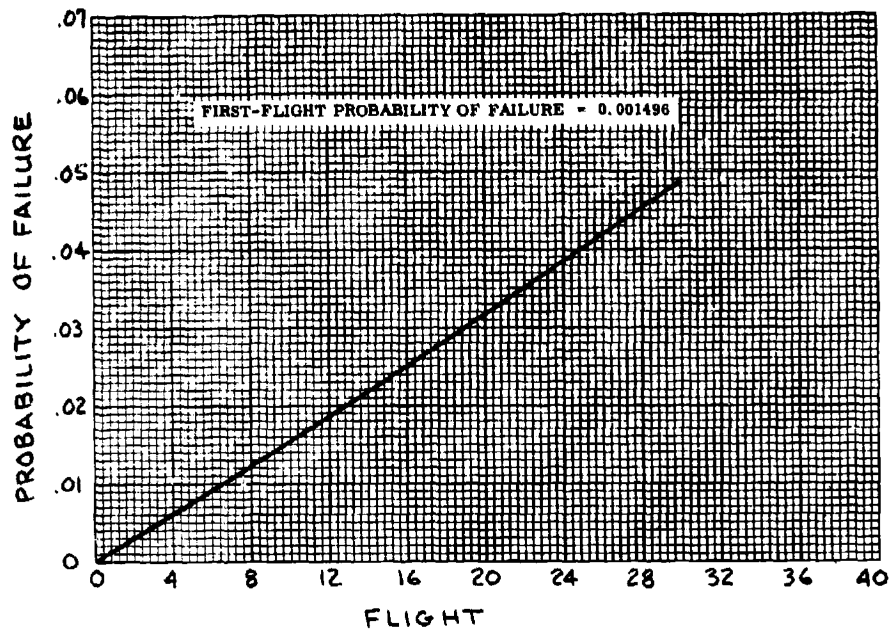


Figure 6-35 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Thermal Conditioning/ Feedline Cooling, Instant Start (C)

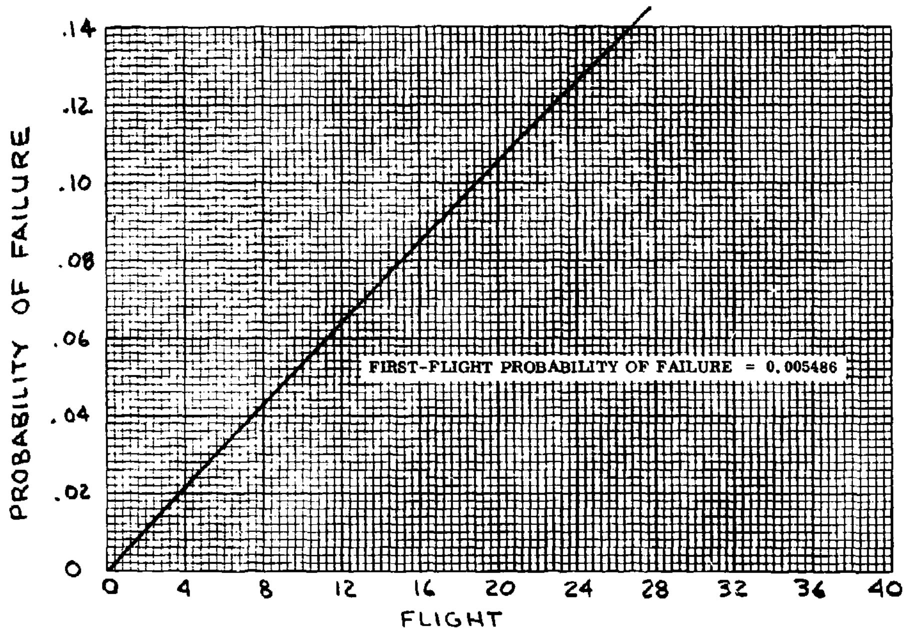


Figure 6-36 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Thermal Conditioning/ Feedline Cooling, Normal Start (C)

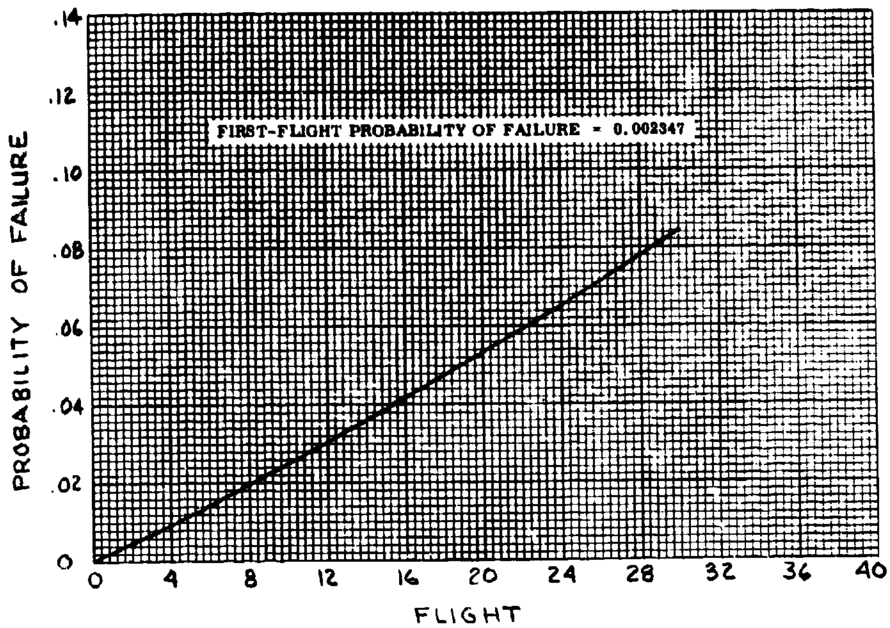


Figure 6-37 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Pressurization System, Instant Start (C)

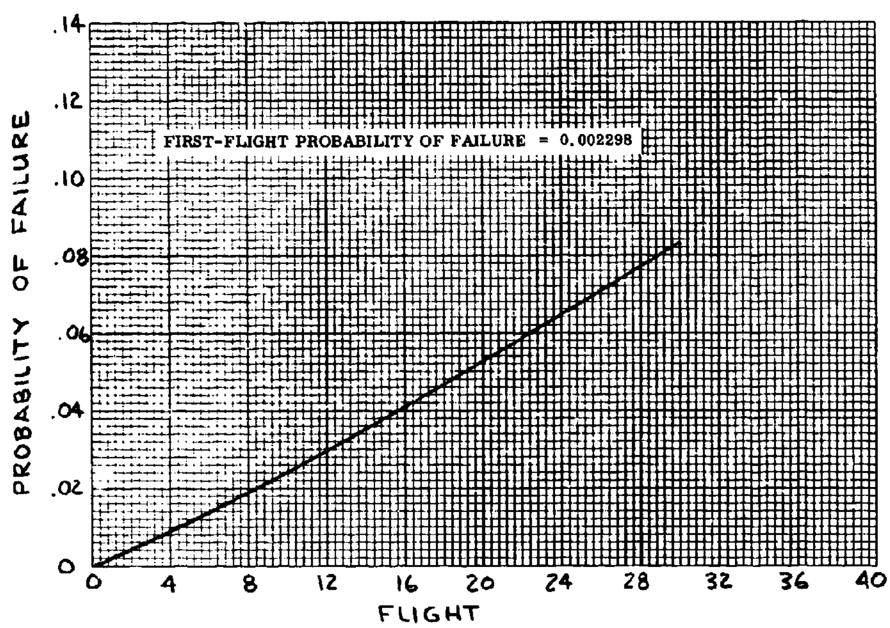


Figure 6-38 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Pressurization System, Normal Start (C)

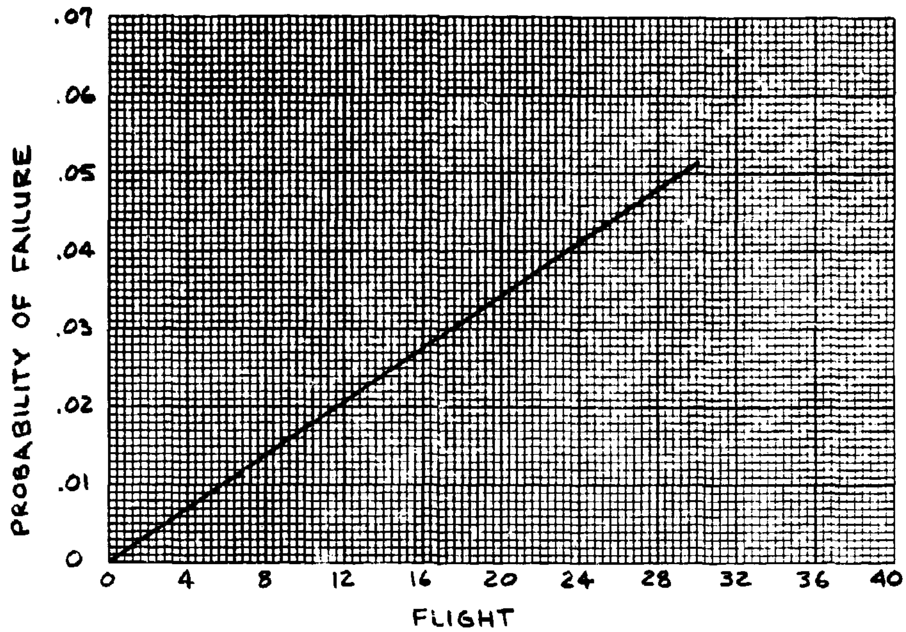


Figure 6-39 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Propellant Utilization, Capacitance Gaging (C)

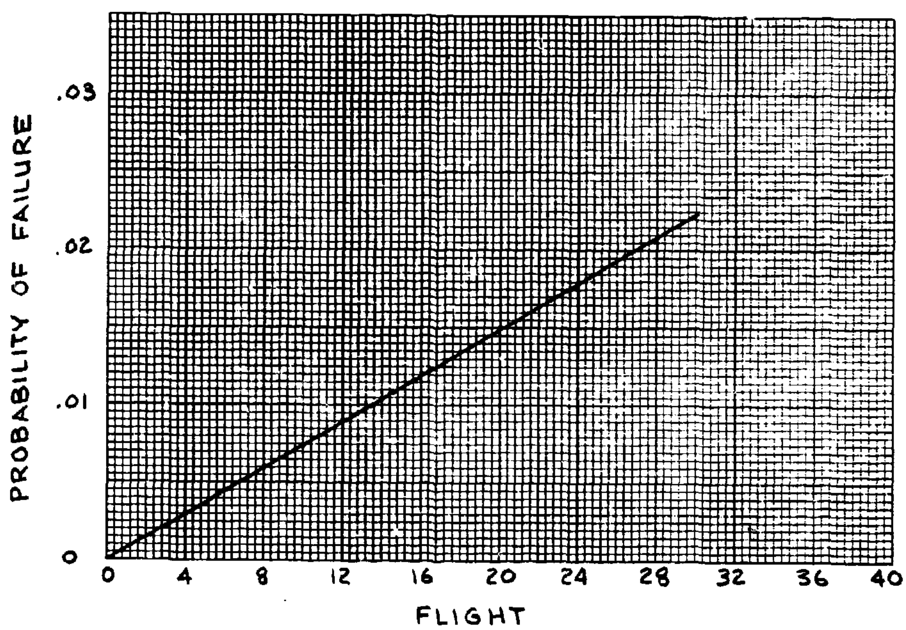


Figure 6-40 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Propellant Utilization, RF Gaging (C)

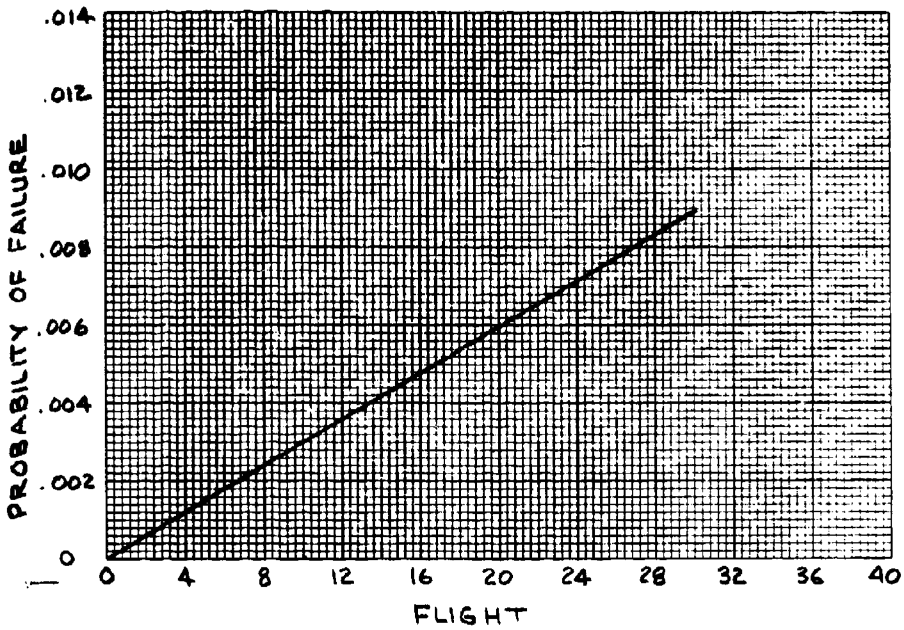


Figure 6-41 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Propellant Utilization, Mass Flowmeter (C)

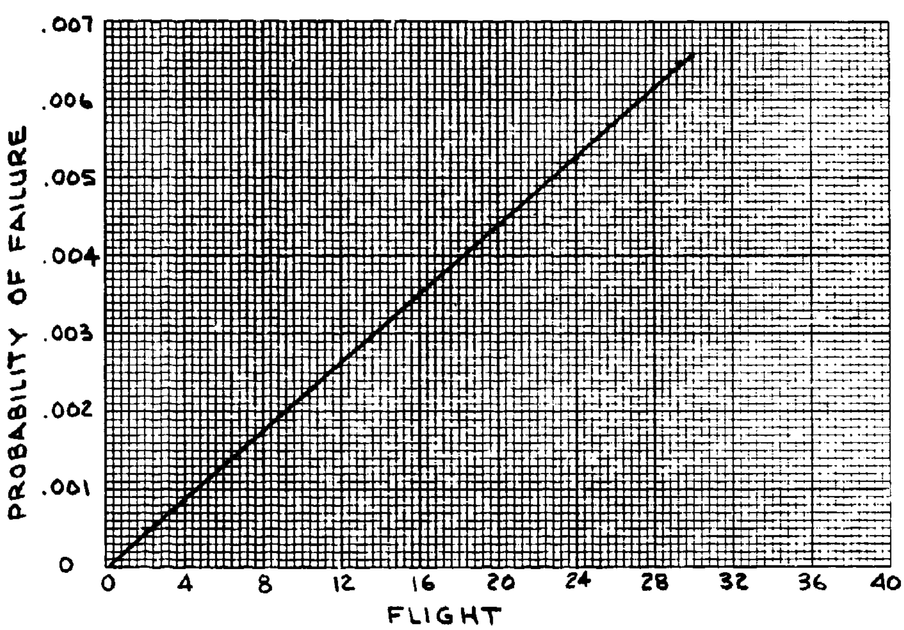


Figure 6-42 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Propellant Utilization, Nucleonic Gaging (C)

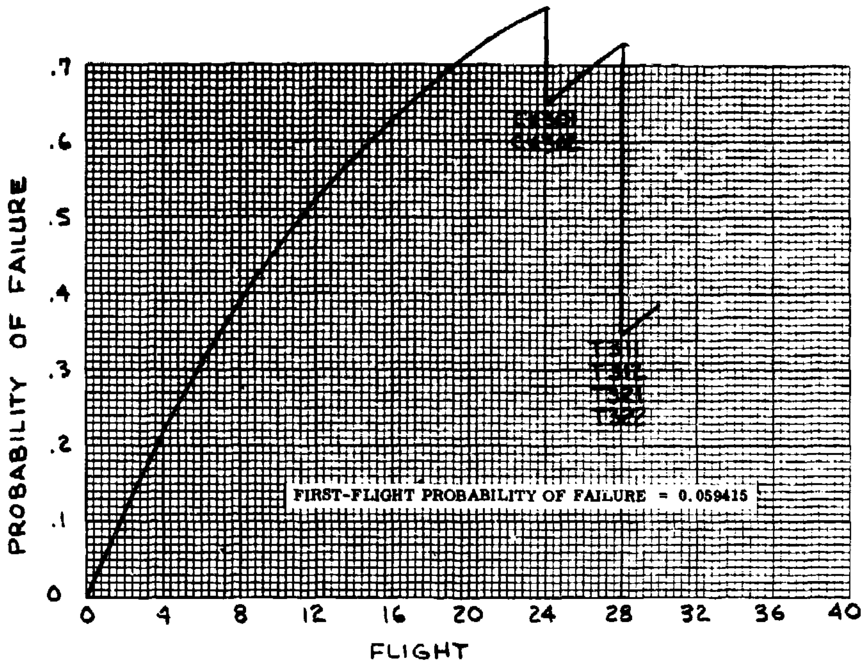


Figure 6-43 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Attitude Control System, Nonintegrated (C)

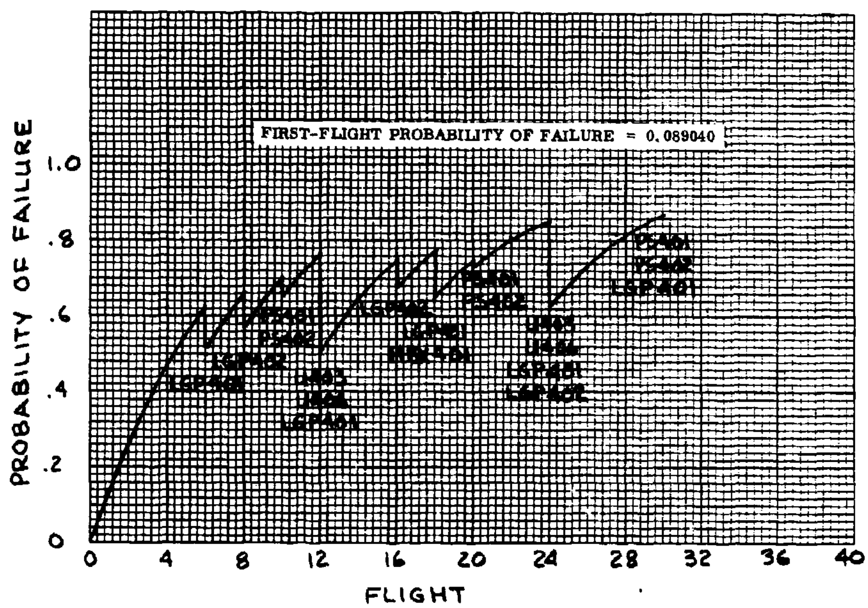


Figure 6-44 Cryogenic Spacecraft (LF_2/LH_2), Mission III, Attitude Control System, Integrated (C)

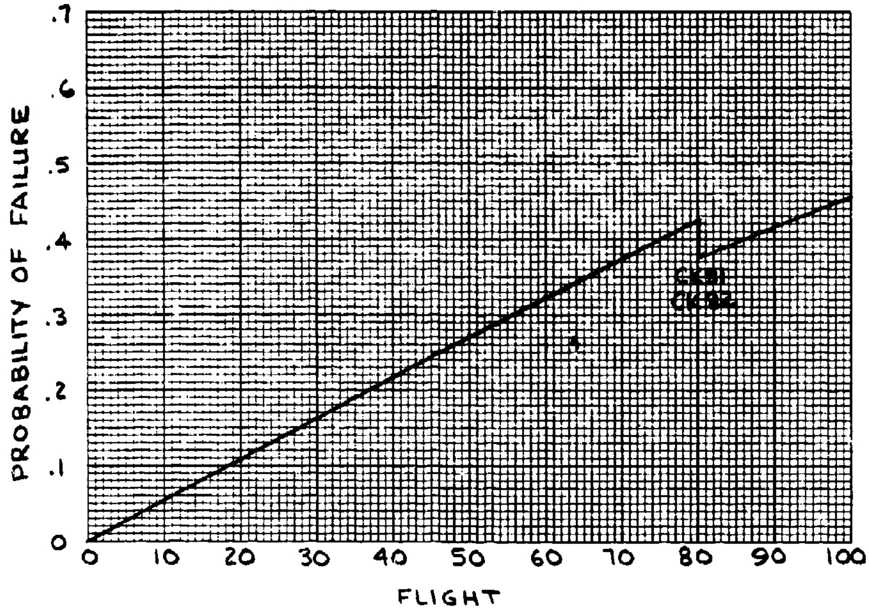


Figure 6-45 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Propulsion System, Instant Start (C)

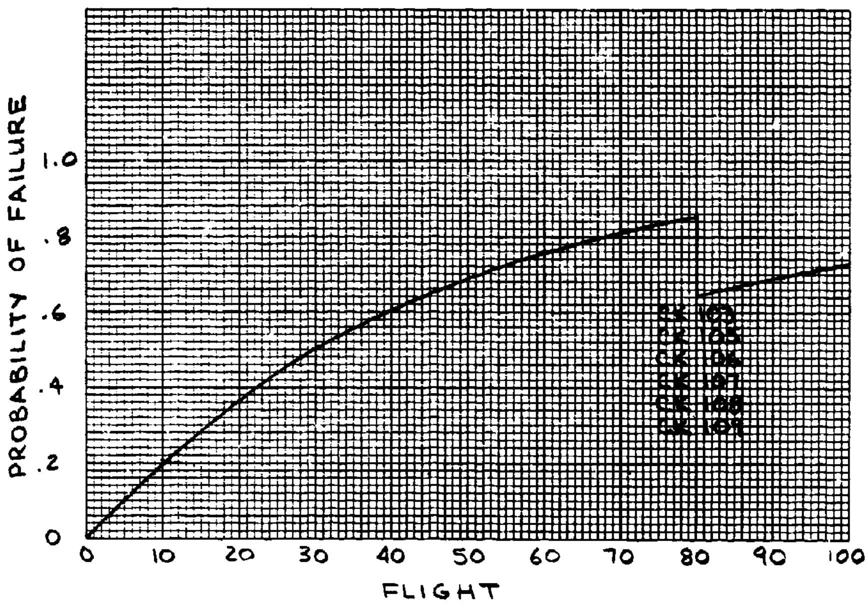


Figure 6-46 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Propulsion System, Normal Start (C)

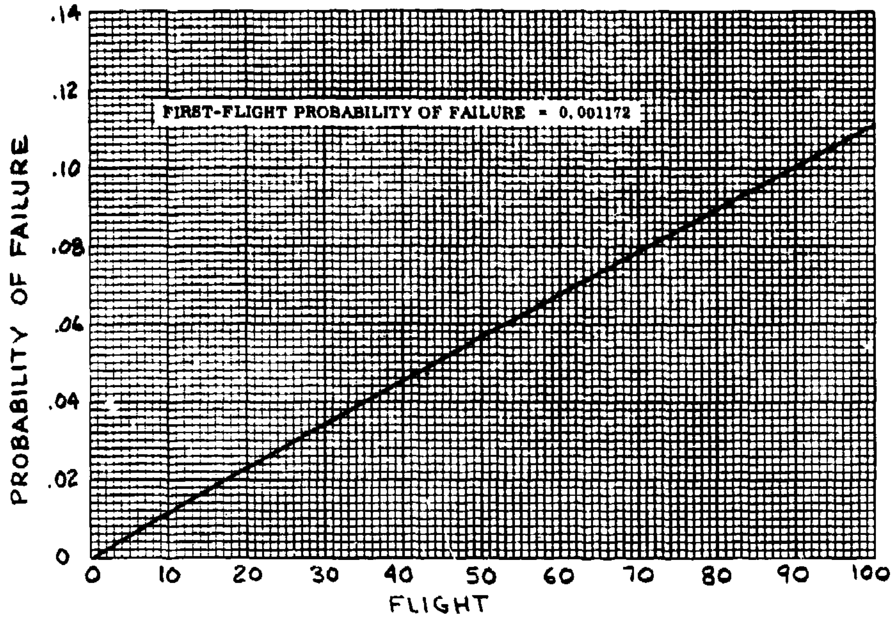


Figure 6-47 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Fill, Drain, and Feed, Instant Start (C)

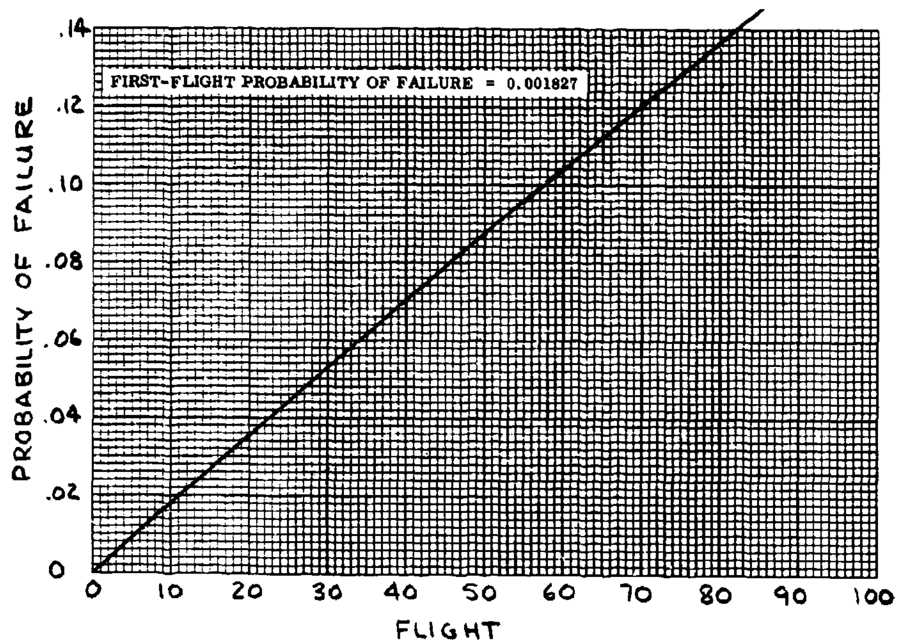


Figure 6-48 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Fill, Drain, and Feed, Normal Start (C)

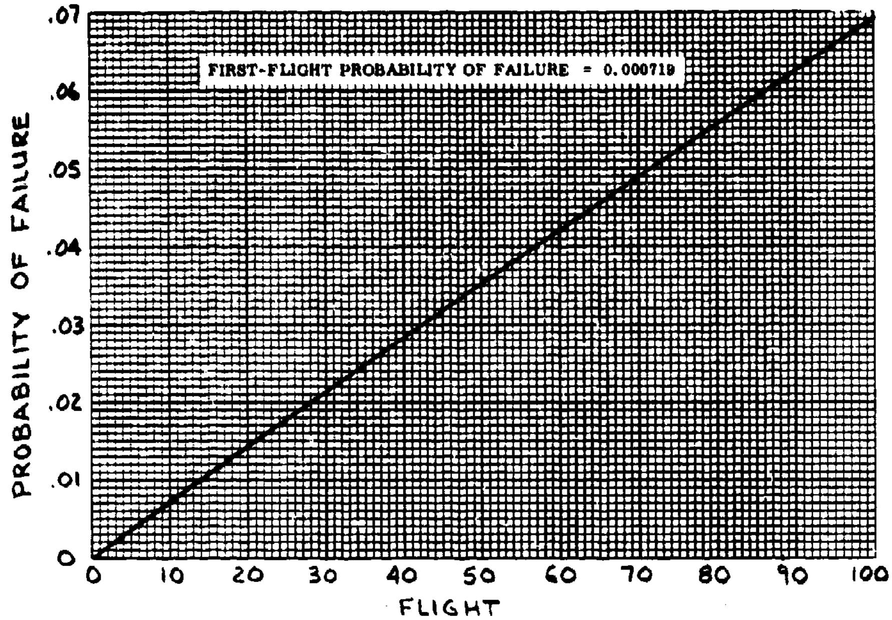


Figure 6-49 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Ground Vent/Emergency Flight Vent, Instant Start (C)

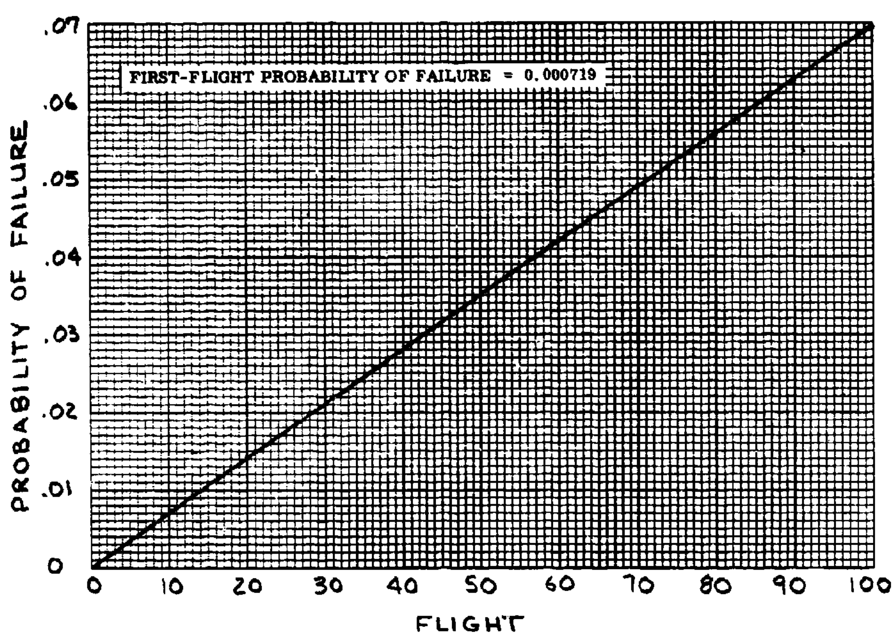


Figure 6-50 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Ground Vent/Emergency Flight Vent, Normal Start (C)

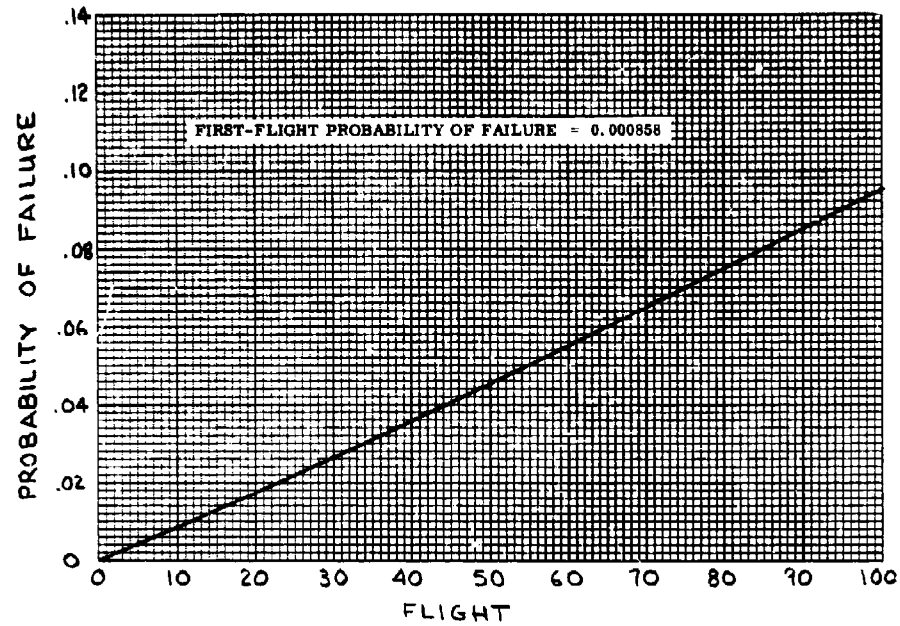


Figure 6-51 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Thermal Conditioning/Feedline Cooling, Instant Start (C)

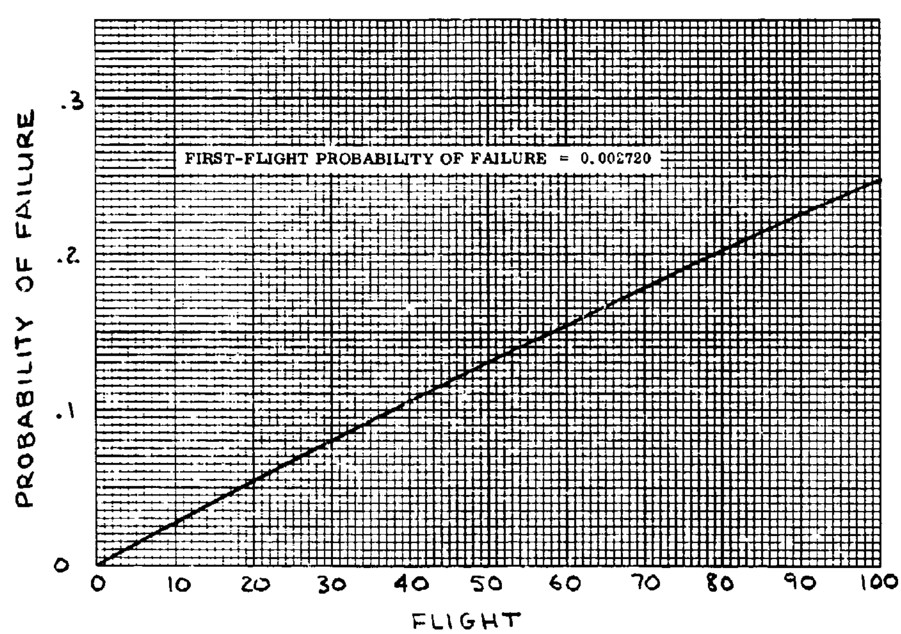


Figure 6-52 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Thermal Conditioning/Feedline Cooling, Normal Start (C)

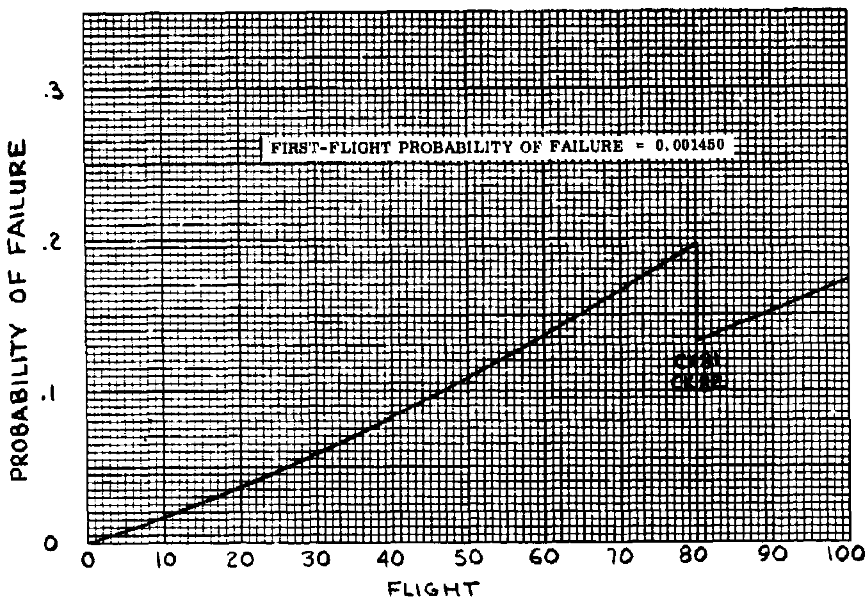


Figure 6-53 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Pressurization System Instant Start (C)

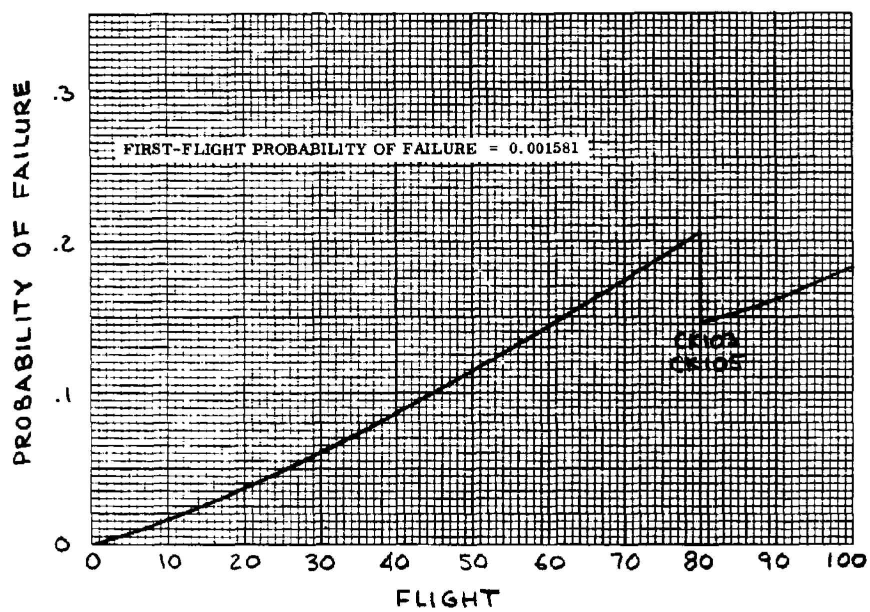


Figure 6-54 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Pressurization System Normal Start (C)

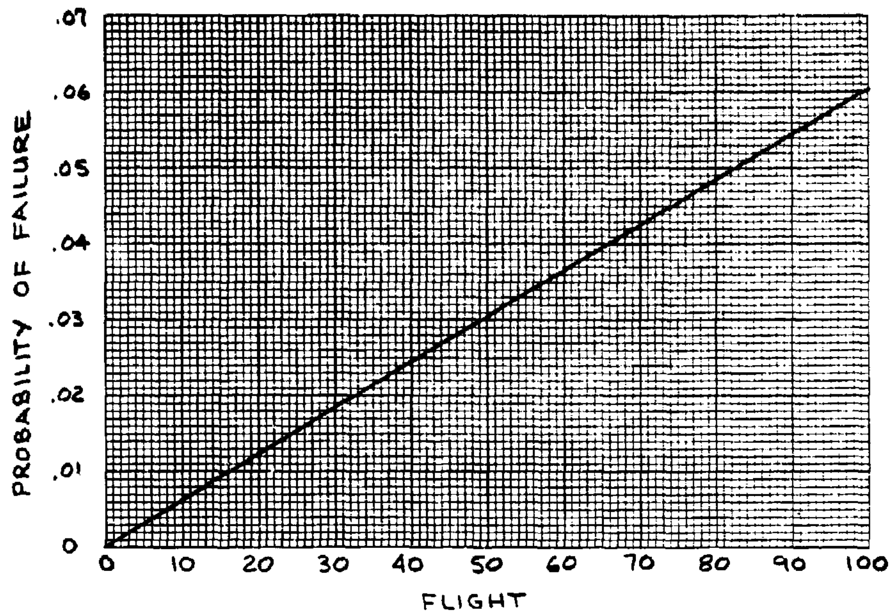


Figure 6-55 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Propellant Utilization, Capacitance Gaging (C)

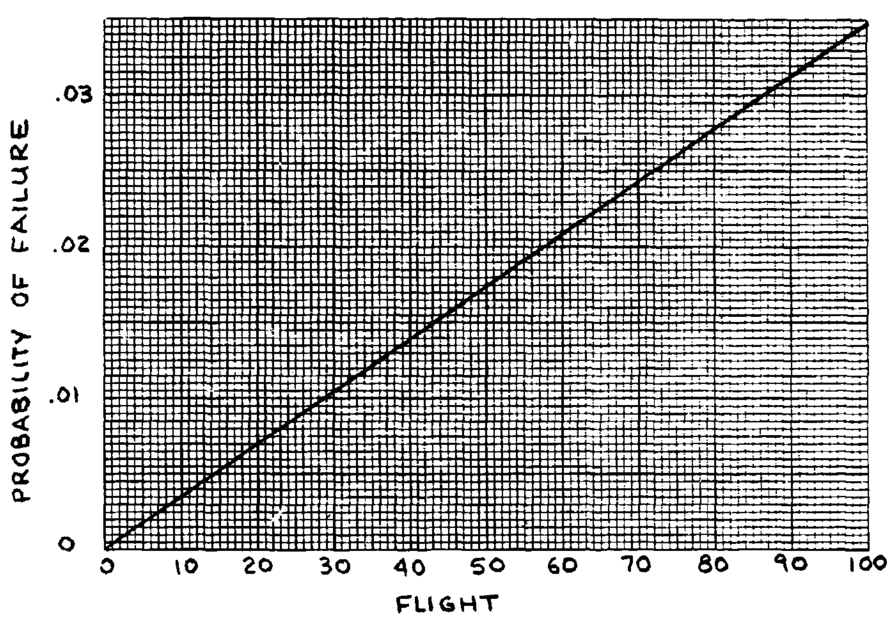


Figure 6-56 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Propellant Utilization, RF Gaging (C)

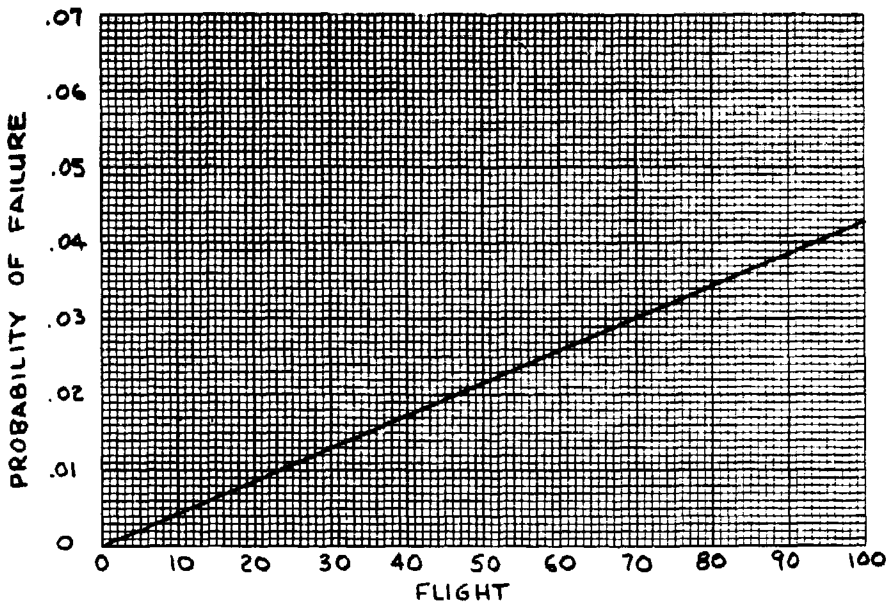


Figure 6-57 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Propellant Utilization, Mass Flowmeter (C)

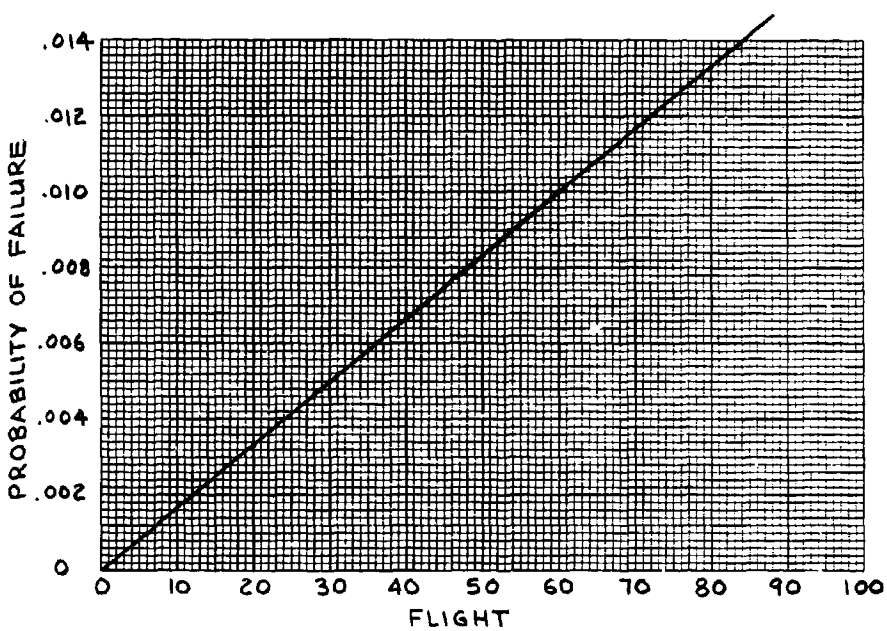


Figure 6-58 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Propellant Utilization, Nucleonic Gaging (C)

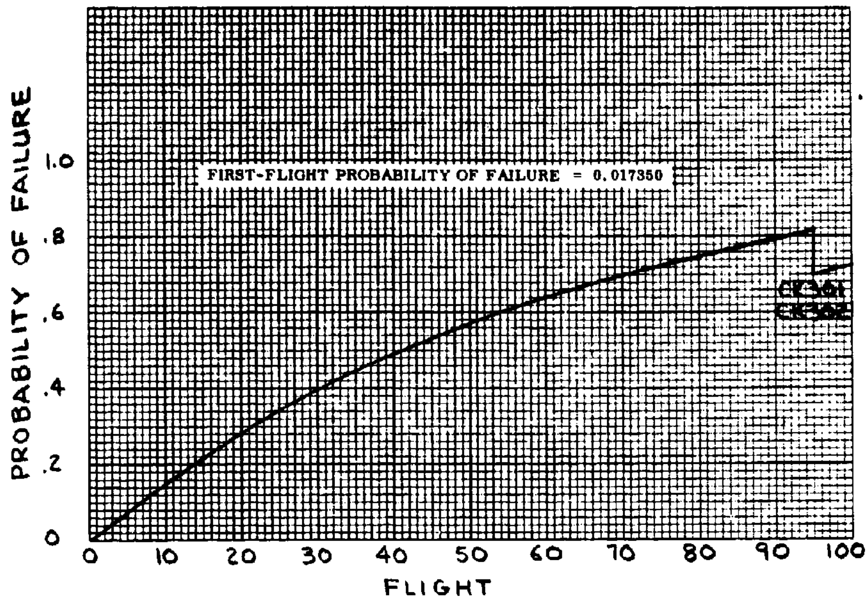


Figure 6-59 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Attitude Control System, Nonintegrated (C)

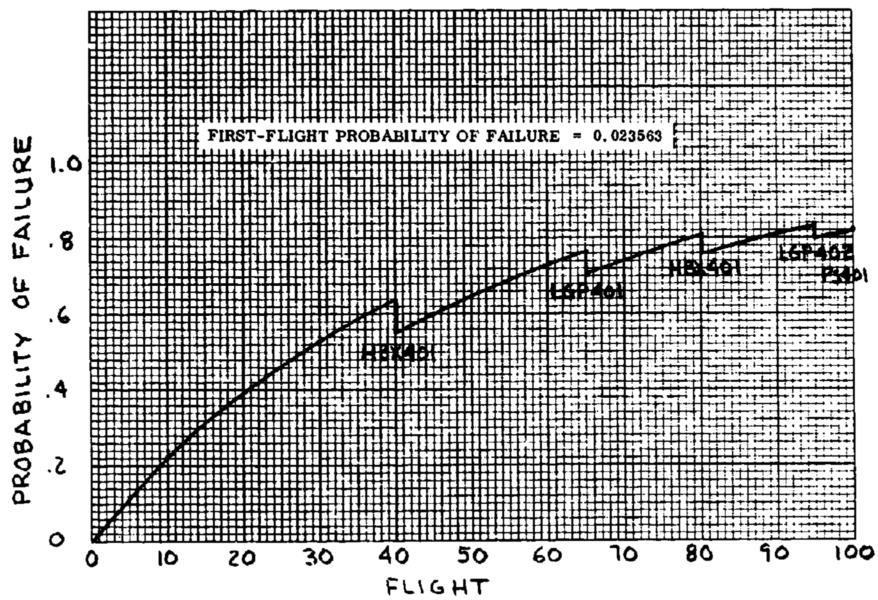


Figure 6-60 Cryogenic Spacecraft (LF_2/LH_2), Mission IV, Attitude Control System, Integrated (C)

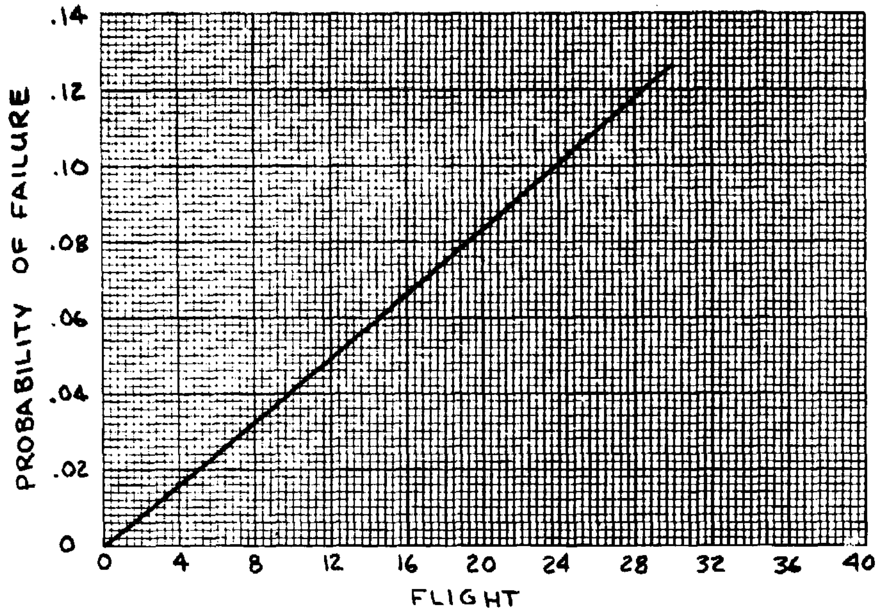


Figure 6-61 Storable Spacecraft (N_2O_4/50-50), Mission III, Propulsion System (C)

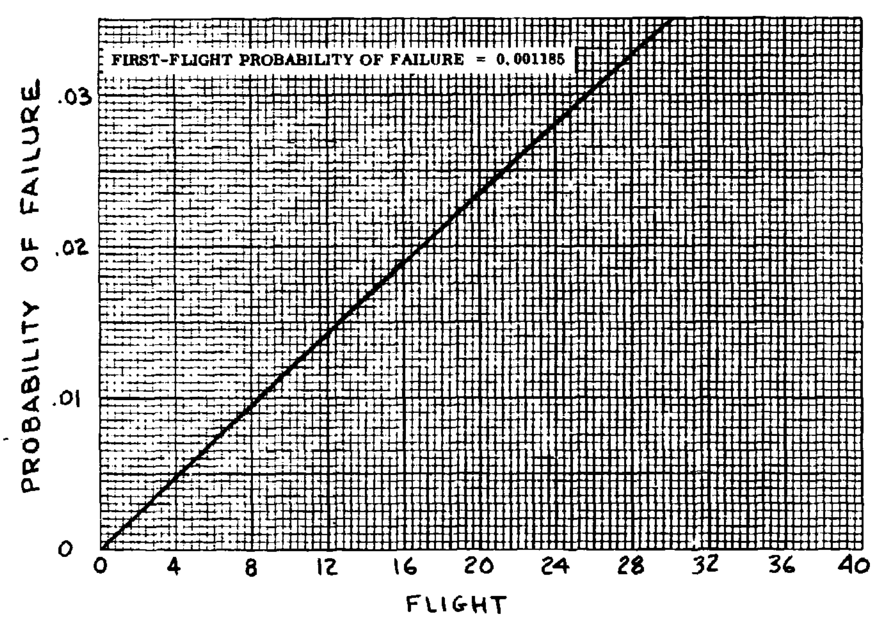


Figure 6-62 Storable Spacecraft (N_2O_4/50-50), Mission III, Fill, Drain, and Feed (C)

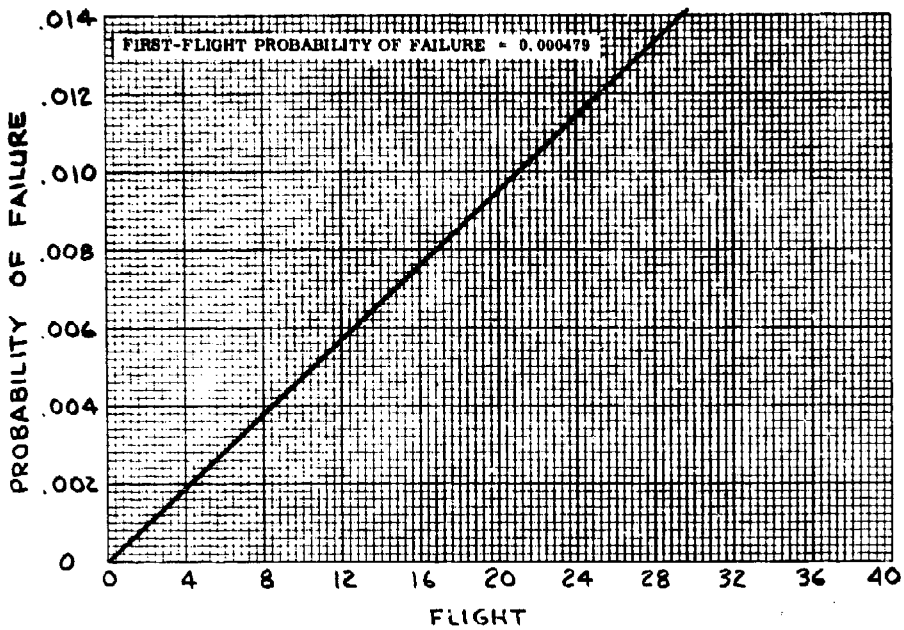


Figure 6-63 Storable Spacecraft (N_2O_4/50-50), Mission III, Ground Vent/ Emergency Flight Vent (C)

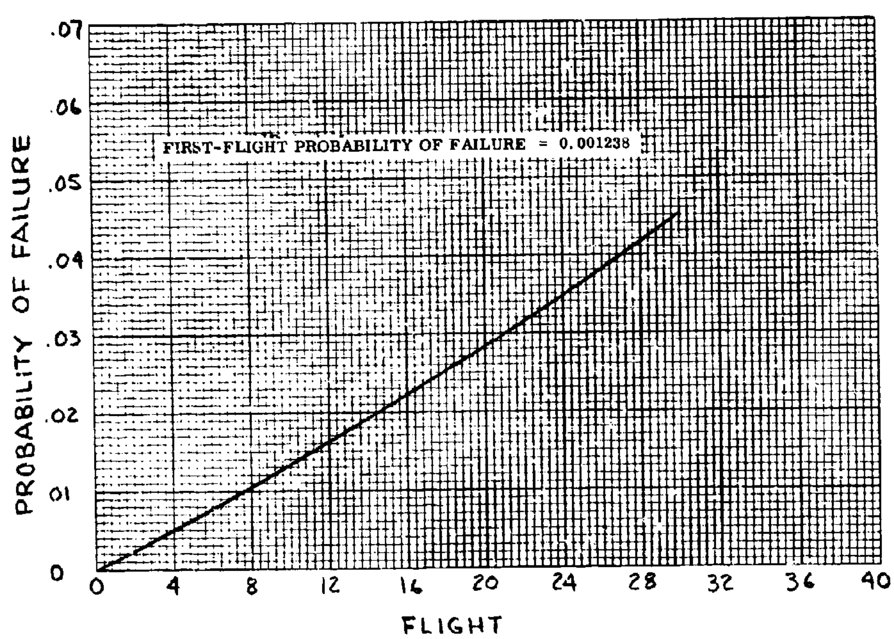


Figure 6-64 Storable Spacecraft (N_2O_4/50-50), Mission III, Pressurization System (C)

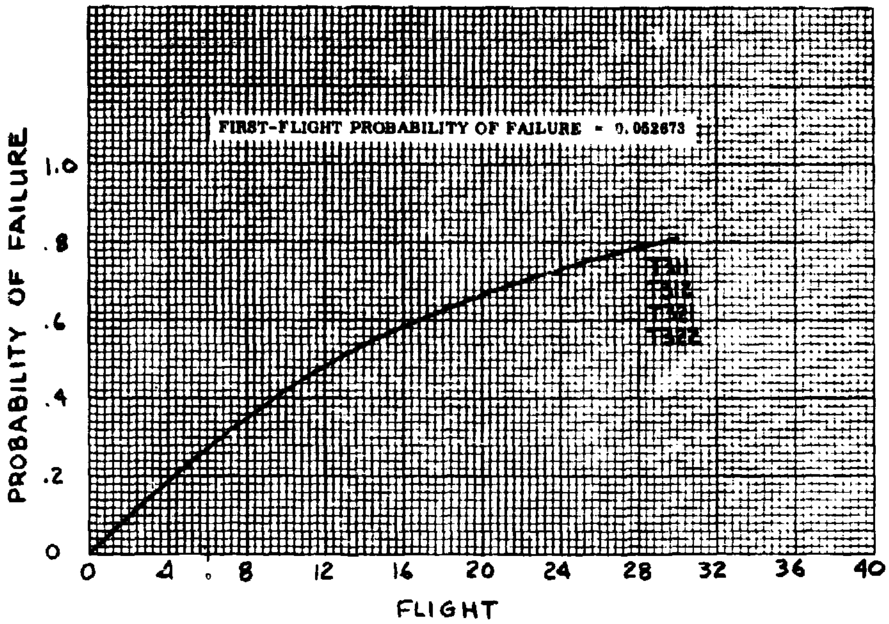


Figure 6-65 Storable Spacecraft (N_2O_4/50-50), Mission III, Attitude Control System, Nonintegrated (C)

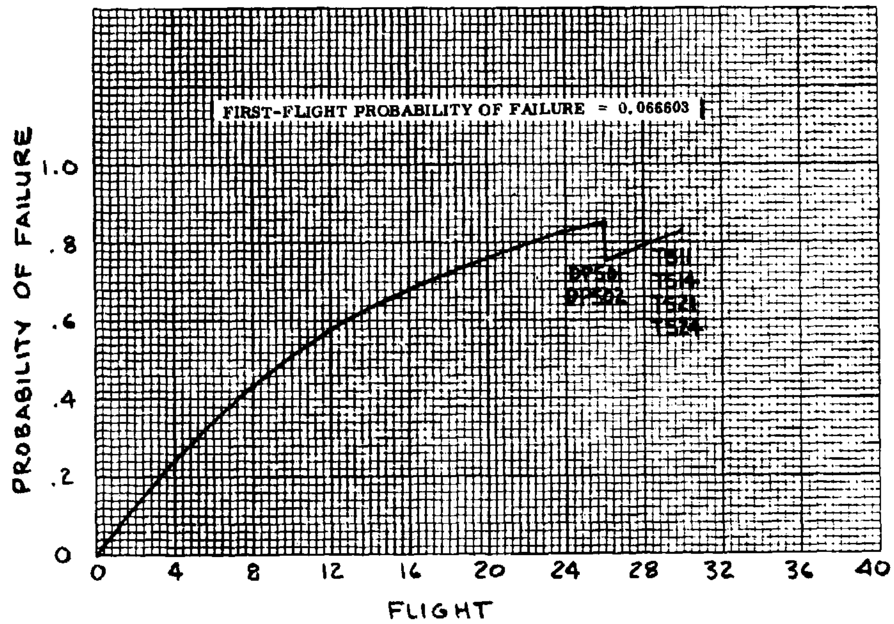


Figure 6-66 Storable Spacecraft (N_2O_4/50-50), Mission III, Attitude Control System, Integrated (C)

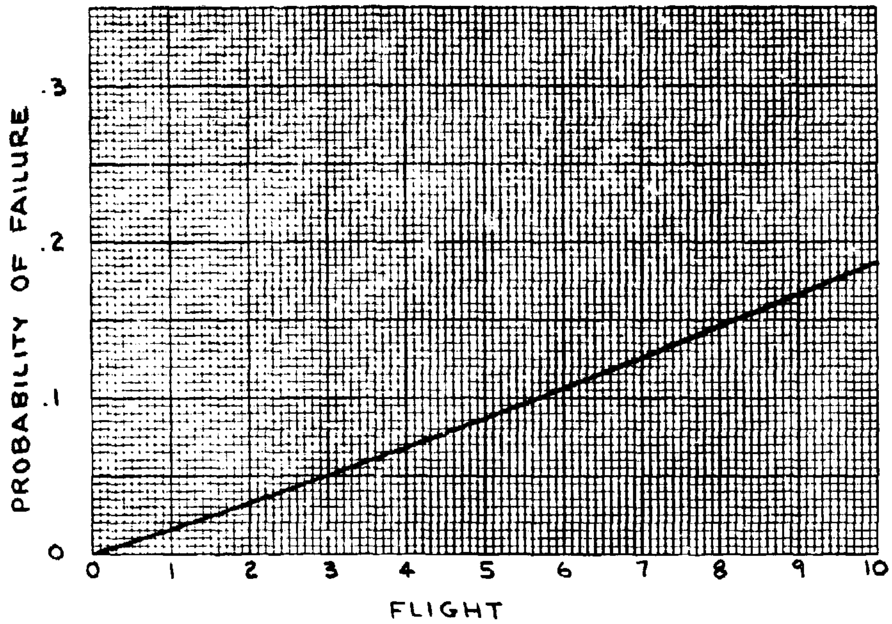


Figure 6-67 Storable Spacecraft (N_2O_4/50-50), Mission V, Propulsion System (C)

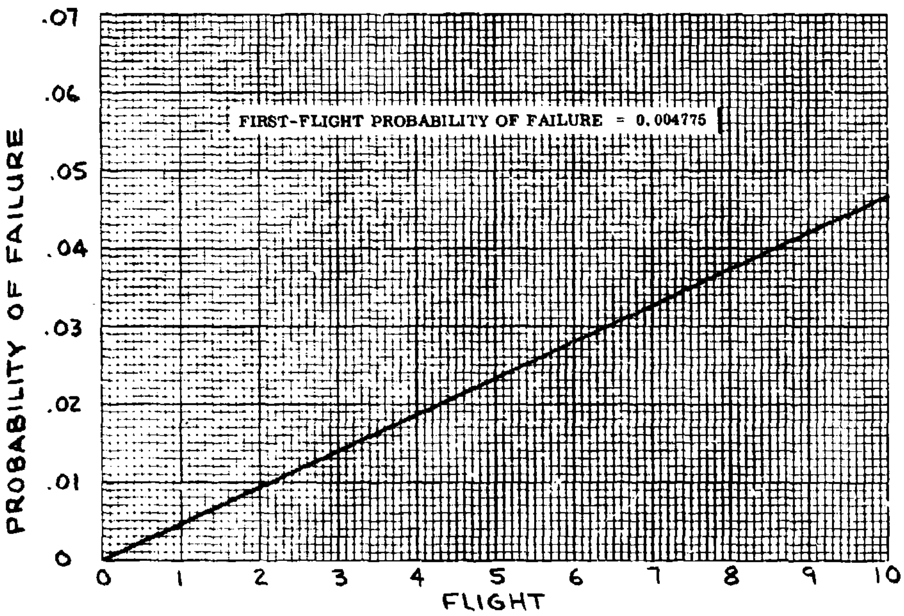


Figure 6-68 Storable Spacecraft (N_2O_4/50-50), Mission V, Fill, Drain and Feed (C)

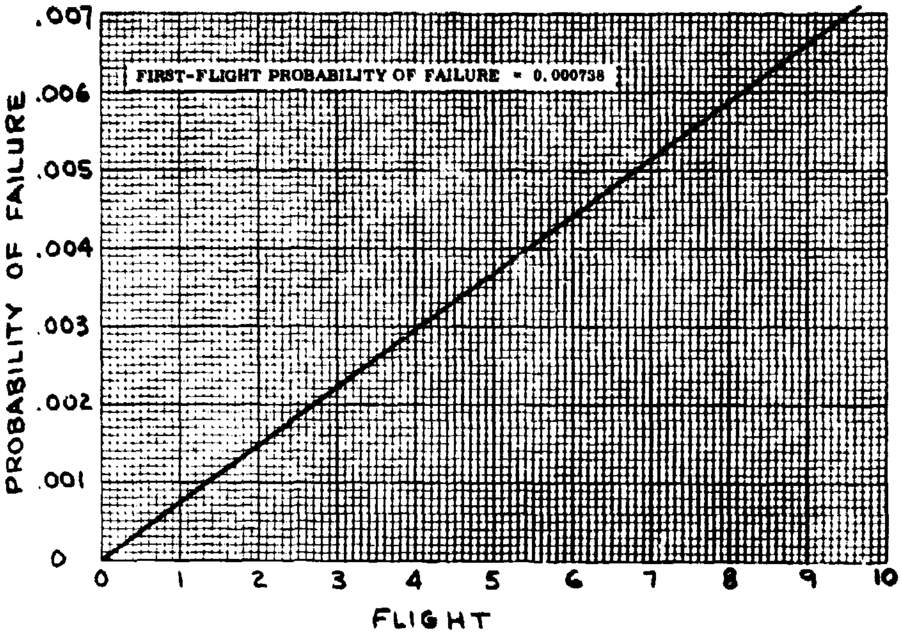


Figure 6-69 Storable Spacecraft (N_2O_4/50-50), Mission V, Ground Vent/Emergency Flight Vent (C)

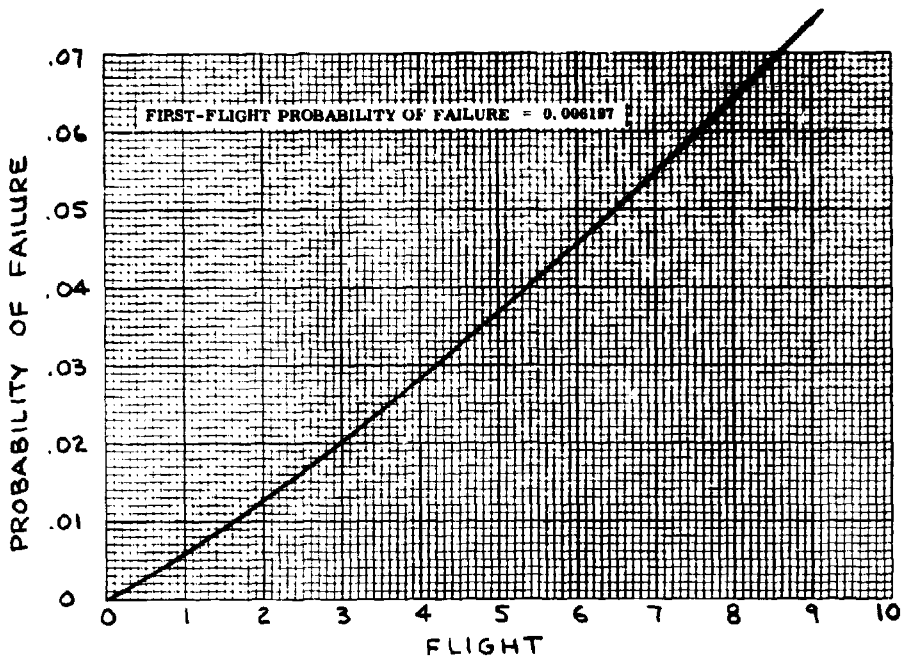


Figure 6-70 Storable Spacecraft (N_2O_4/50-50), Mission V, Pressurization System (C)

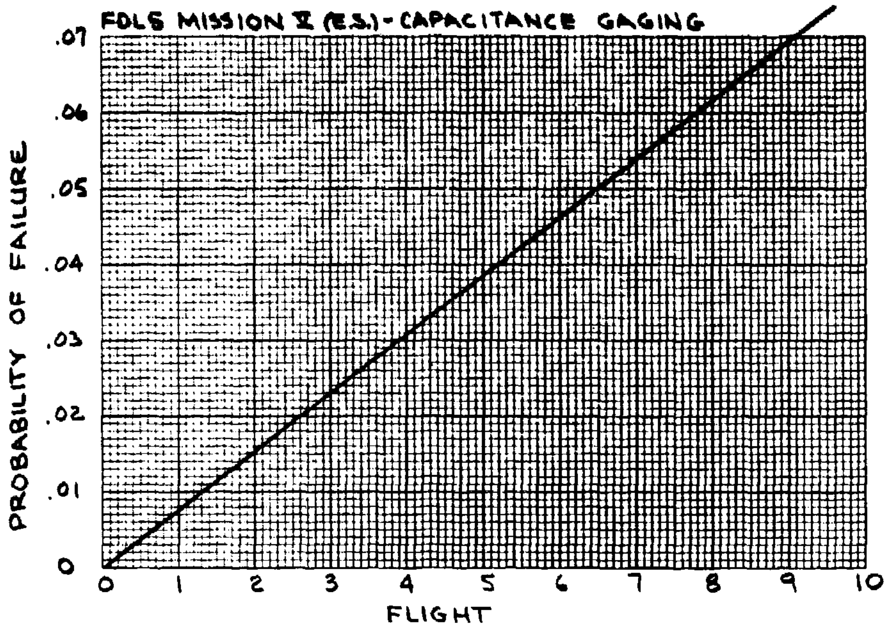


Figure 6-71 Storable Spacecraft (N_2O_4/50-50), Mission V, Propellant Utilization, Capacitance Gaging (C)

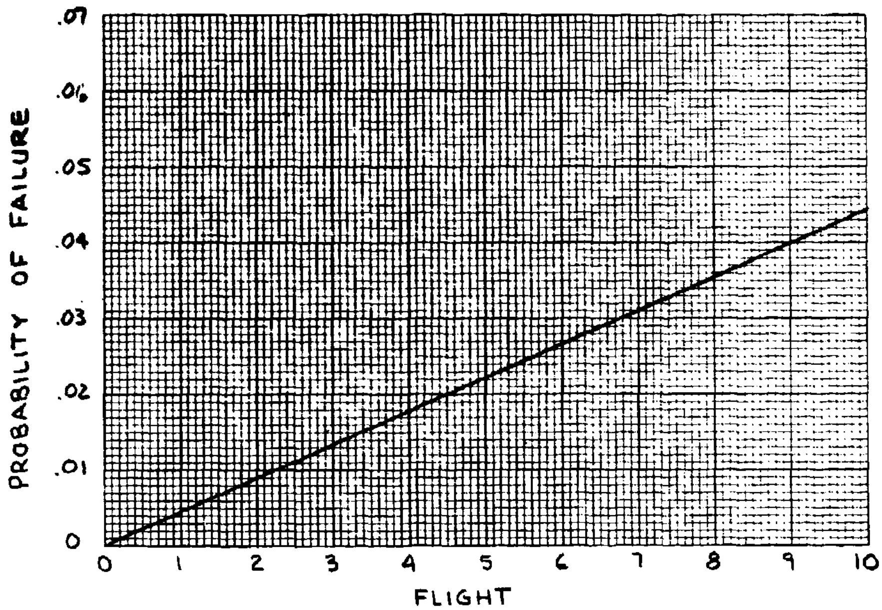


Figure 6-72 Storable Spacecraft (N_2O_4/50-50), Mission V, Propellant Utilization, RF Gaging (C)

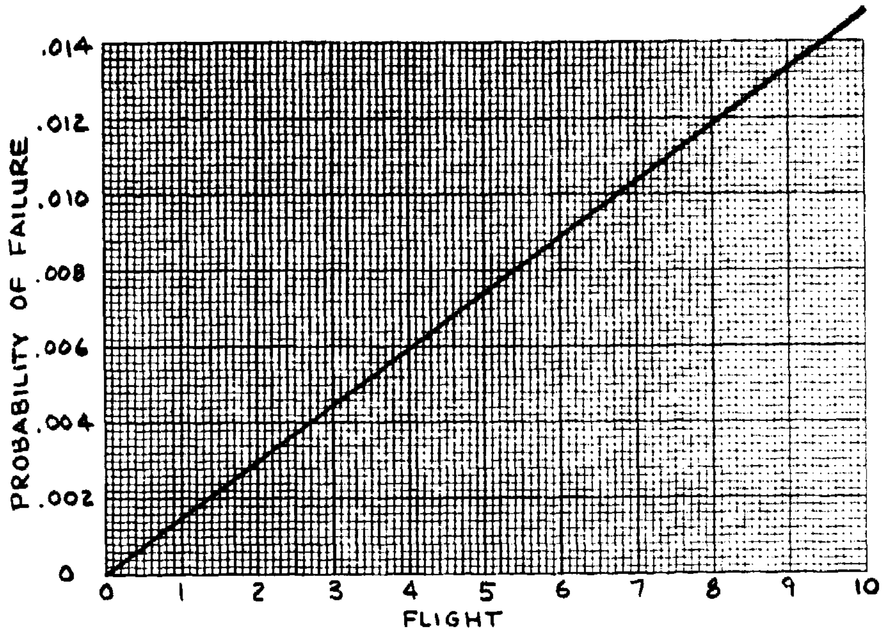


Figure 6-73 Storable Spacecraft (N_2O_4/50-50), Mission V, Propellant Utilization, Mass Flowmeter (C)

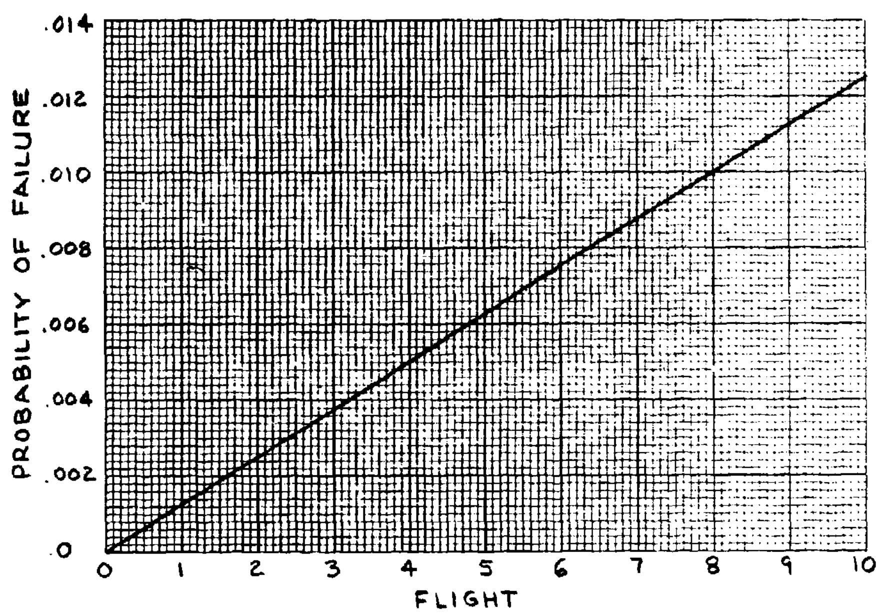


Figure 6-74 Storable Spacecraft (N_2O_4/50-50), Mission V, Propellant Utilization, Nucleonic Gaging (C)

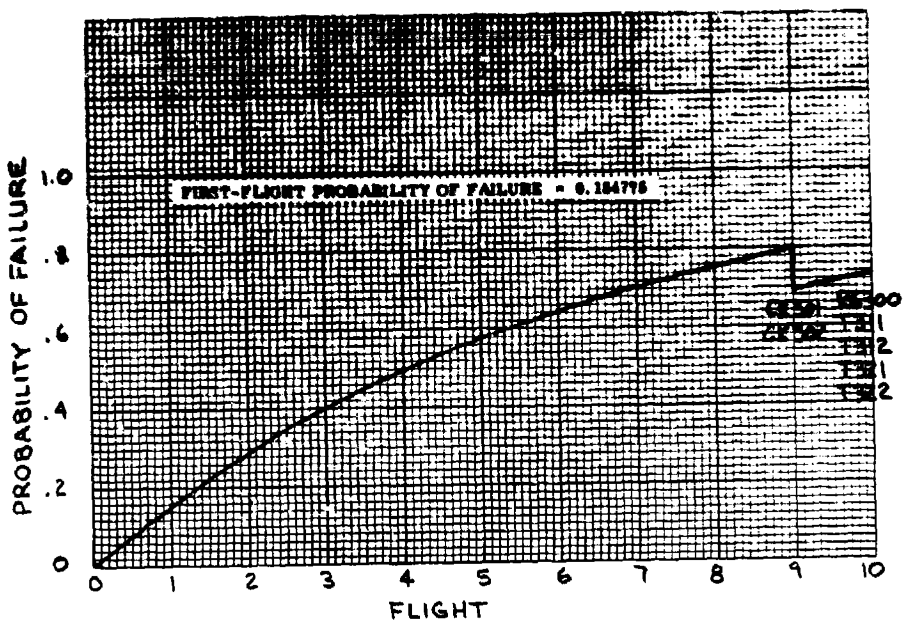


Figure 6-75 Storable Spacecraft (N_2O_4/50-50), Mission V, Attitude Control System, Nonintegrated (C)

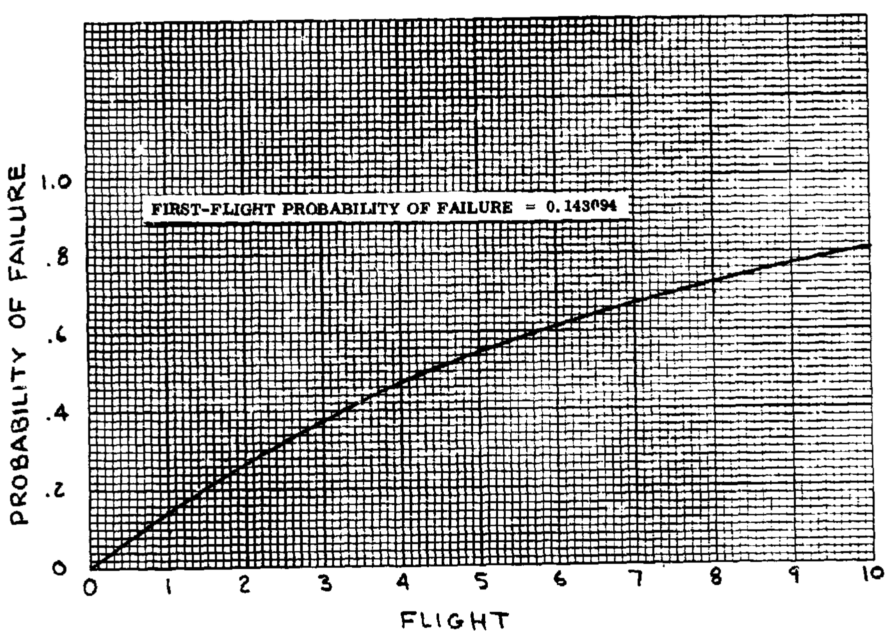


Figure 6-76 Storable Spacecraft (N_2O_4/50-50), Mission V, Attitude Control System, Integrated (C)

6.4 QUALIFICATION OF COMPONENTS AND SUBSYSTEMS (U)

(U) An examination was made of the qualification philosophies currently in practice in commercial aviation, military aerospace, and NASA. A summary of the results is presented in Table 6-19. This summary points out that several techniques are applicable to qualification:

- Environmental testing
- Comparative or historical data
- Similarity
- Analytical method

(U) Qualification through complete environmental testing is the most common approach for military systems. The comparative data or historical data method is applicable where component design remains relatively unchanged. Qualification of components by similarity to a qualified component is an acceptable technique, but has very limited application because of variations in operating conditions and environments. The analytical method is highly sensitive to the accuracy of the assumed model.

(U) There is no indication that the introduction of reusable vehicles will have an initial impact upon the current philosophy of environmental testing. As advancements in reusable vehicle applications occur, there may be a gradual shifting to qualification by historical data or similarity, as is practiced in commercial aircraft. One method in practice which is capable of reducing component and subsystem qualification costs is the employment of "qualification by next level test." This considers that if, for example, the component performs so as to allow the subsystem to be qualified, then the component is qualified. While there are some risks involved in this approach, it would appear that the present state of the art as applied to reusable vehicles should allow more application of this technique.

Table 6-19

QUALIFICATION PHILOSOPHY
(UNCLASSIFIED)

	Commercial Aircraft	Military Vehicles
Specifications Utilized	FAA	MIL STDS., FED Specs., NASA, JAN, DOD, LMSC
Cognizant or Approving Agency	FAA, Airline Customer	Military Customer
Deviations Allowed	Mfg. can challenge need to qualify or request spec. deviation	Cannot change specs. or requirements. May request deviations
Component Testing	• Emphasis on historical data • May qualify new designs based on similarity • Spec. by FAA • May qualify by next level test	• Utilize historical data but designs and environments change rapidly and all components have to be qualified or requalified. • Derive cycle data
System Testing	• May qualify new designs based on similarity • Spec. by FAA • May qualify by vehicle level test • Facility, cost, and schedule constraints may affect decision	• Perform 100 percent system test unless absolutely impossible. • Perform by ground test before flight test (except special program, i.e., SR-71)
Vehicle Testing	• FAA approval • Customer approval • Approval on first vehicle qualified approves rest	• Military customer approval. • Qualifications may extend over several vehicle flight, dynamic, and other test programs
Facility Constraints	• Can be limiting factor in component or system test, thereby requiring next level testing and acceptance	• Generally facilities will be provided for special tests unless schedule is overriding

(U) A large number of military and NASA specifications were examined in the course of this study. In general most of these were found to be of only minor applicability to the accomplishment of this task. The two specifications examined in detail for recommended modifications were:

MIL-P-27409	–	Propellant Feed System, Rocket Propulsion, General Specification For, 20 March 1967
MIL-C-27410	–	Components, Rocket Propulsion Fluid System, General Specification For, 15 Nov 1966

(U) In general, it was noted in the examination of these and other specifications, that many of the detailed requirements which would be influenced by reusability are normally established by the "model" specifications. It was concluded that the approach would be to modify the two specifications (MIL-P-27409 and MIL-C-27410) with regard to general requirements and to also include within the specification, in the applicable section, information with regard to environmental and related requirements. This, in effect, produced a "general model specification." This approach was implemented and the specifications are presented in Appendix B.

Section 7
SUBSYSTEM TRADEOFFS (U)

(U) The information provided in the previous sections has been utilized as a basis for comparison of the subsystems to determine the most logical selections based upon the available information. As pointed out in Section 6, and elsewhere, the selection of the subsystems is naturally very dependent upon the conditions and design features of the reference vehicles. However, an attempt has been made to generalize the conclusions, and to provide suitable alternate selections where possible. Also, in some instances, the choices are influenced by existing technoligies and available data. Advances in technology could alter the decisions.

7.1 OBJECTIVES AND SCOPE (U)

(U) The objective of this task was to complete the selection of particular subsystems from the alternatives. The selections are supported with the rationale and comparisons of advantages and disadvantages of the various alternatives.

7.2 REUSABLE LAUNCH VEHICLE (LO_2/LH_2) (C)

(U) The Reusable Launch Vehicle was given considerable attention in the tradeoff studies since it presented the largest number of possible subsystems and presented many problems common to reusability. The subsystem tradeoffs which were indicated to present the most influence upon the reference vehicles were selected for evaluation.

7.2.1 LO_2/LH_2 Engine Operational Mode (C)

(U) The orbital transfer, orbital maneuvers, and retro of the Reusable Launch Vehicle requires considerable propellant, and requires several starts. These maneuvers re require only a low thrust to weight ratio, and only one of the main engines is required.

(C) The mode of operation of the engine has considerable impact upon the propulsion subsystems. The operation of the engine at approximately 10 percent thrust requires an engine cooldown and an operation in the normal pumped mode. If it is possible to operate the engine in a non-pumped idle mode (i.e., a pressure-fed engine operation), engine cooldown and propellant conditioning may be assumed to be unnecessary. Another possibility exists that the engine could be started using a non-pumped idle mode, and then proceed to 10 percent thrust after the engine is sufficiently cooled down.

(U) Using the engine cooldown information which was provided in Section 3 (supplied by Pratt and Whitney) and examining the mission, the resulting propellant requirements are presented in Table 7-1.

Table 7-1

LO_2/LH_2 ENGINE OPERATIONAL MODE,
EFFECT ON PROPELLANT REQUIREMENTS (C)
(CONFIDENTIAL)

Operational Mode	I_{sp}	Mission	Cool-down Propellant	Orbital ΔV Propellant	Total Propellant
Low Thrust (10%)	456	I	8,550	8,290	16,870
		II	10,260	6,770	17,030
Non-pumped Idle Mode (1% thrust)	440	I	Neg	8,600	8,600
		II	Neg	7,015	7,015
(1) Non-pumped Idle start	440	I	(Must utilize 8550)	8,600	8,600
(2) Low Thrust Operation	456	II	(Must utilize 10,260)	7,015	7,015

(U) As may be seen, there is considerable propellant weight saving using the idle mode to eliminate cooldown requirements. The idle mode start followed by engine operation is not applicable, because if it is assumed that the same quantity of cooldown propellant must pass through the engine before low thrust is initiated, the required velocity propellant is less than the cooldown propellant and the mode is not applicable.

(C) There are several other aspects to the comparison of the modes of engine operation which are presented in Table 7-2. As is pointed out in this comparison, the idle mode has one serious disadvantage in that engine bleed is not available because the pumps are not running, and this would require a helium pressurization system for both the liquid oxygen tank and the liquid hydrogen tanks, or some equivalent external system which would increase the pressure of liquid hydrogen and oxygen and convert these to gas for pressurization.

(U) The low thrust mode of operation has the disadvantage that in addition to cooldown, there are problems relative to propellant orientation, as shown in Table 7-3. If the low thrust mode of operation is used, then the only attractive method, as shown in Table 7-3, is to provide for keeping the feedlines full. Pump recirculation methods are not satisfactory, since this introduces additional orientation problems. Therefore, the only method considered attractive would be to use a surface tension device to hold the propellants in the feedline and to employ sump and feedline continuous cooling, down to a point reasonably near the pump, through the use of a thermal conditioning unit.

(U) The alternative to idle mode or low thrust operation is to employ a secondary propulsion subsystem for these orbital velocity requirements. This would require development of a suitable engine and related propellant supply system. If this engine were to operate as part of the attitude control subsystem, then engine bleed would not be available, and some external pressurization source would have to be provided.

Selected LO_2/LH_2 Engine Operational Mode (C)

(C) In consideration of the factors involved, the idle mode of engine operation appears to be the most attractive approach, provided that either liquid or gas can be employed in the engine. This would require a liquid to gas conversion system for both the LH_2 and LO_2 tanks to provide pressurization in order to prevent the necessity for helium.

CONFIDENTIAL

Table 7-2

REUSABLE LAUNCH VEHIC
COMPARISON OF ENGINE OPERAT
(CONFIDENTIAL)

Identity	Co	
	1	2
Engine operational mode in orbital transfer, orbital maneuvering, and retro	Description: Non-pumped idle operation Advantages: 1. Manifold lines may be mixed phase 2. Lower cooldown propellant requirement Disadvantages: 1. Loss in specific impulse 2. Possible thrust variations 3. Pressurized engine bleed not available	Description: Low Thrust operation Advantages: 1. Probably less thrust variat than non-pumped idle 2. Optimium mixture ratio sa as high thrust 3. Pressurized engine bleed available Disadvantages: 1. High cooldown propellant requirements 2. Propellant lines must conta liquid at time engine starts requiring either: a. Large propellant containment device b. Liquid in lines at all

1

Table 7-2

: LAUNCH VEHICLE,
ENGINE OPERATION MODES (C)
NFIDENTIAL)

Comparison Matrix		
2	3	4
operation less thrust variation pumped idle mixture ratio same rust ed engine bleed s: down propellant ents t lines must contain ime engine starts, either: ge propellant ainment device id in lines at all times	Description: 1. Non-pumped idle start 2. Low thrust operation Advantages: 1. Manifold lines may be mixed phase during start 2. Mixture ratio during operation same as high thrust 3. Pressurized engine bleed available Disadvantages: 1. No propellant savings over non-pumped idle 2. Engine must have all characteristics of non-pumped idle	Description: Alternate propulsion system (large integrated attitude control system) Advantages: 1. No cooldown 2. Low propellant orientation requirement Disadvantages: 1. Additional weight 2. Additional development 3. Pressurization bleed not available

2

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 7-3

REUSABLE LAUNCH VEHICLE, COM
PROPELLANT ORIENTATION METHODS FOR 10 PE
(CONFIDENTIAL)

		(
Identity	1	2
Propellant orientation for 10 percent thrust engine operational mode	Description: Feed lines to engines kept full at all times and cooled by TCU Advantages: 1. Rapid start 2. Passive propellant orientation 3. Smaller orientation devices Disadvantages: 1. Semiactive system 2. Increased heat leak	Description: Feed lines to engines emptie between engine operations. : from tanks during start Advantages: 1. Completely passive syste 2. Low heat leak situation Disadvantages: 1. More variation in startup transients 2. Large propellant orientat device required 3. Line propellants lost afte each engine shutdown 4. Very inefficient for deorb engine operation

1

Table 7-3

CH VEHICLE, COMPARISON OF
THODS FOR 10 PERCENT THRUST OPERATION (C)
(CONFIDENTIAL)

Comparison Matrix		
2	3	4
ion: to engines emptied engine operations. Filled ks during start	Description: Feed lines to engines emptied between engine operations. Cooled down by circulating pump before start	Description: Feed lines to engines kept full and circulated during dormant periods with pumps
es: pletely passive system heat leak situation	Advantages: 1. Low heat leak situation	Advantages: None apparent
tages: e variation in startup sients ge propellant orientation ce required propellants lost after engine shutdown inefficient for deorbit ne operation	Disadvantages: 1. Requires boost pumps and power 2. Large propellant orientation device required or active propellant orientation 3. Line propellants lost after each engine shutdown 4. Very efficient for deorbit engine operation	Disadvantages: Not compatible with passive orientation devices

2

(U) Alternate: The selected alternate method would be the employment of a secondary propulsion subsystem for these operations. A liquid to gas conversion system for pressurization would also have to be provided for this subsystem.

7.2.2 LO_2/LH_2 Pressurization Subsystem Tradeoffs (C)

(C) The LO_2/LH_2 pressurization subsystems must be examined both from the standpoint that the selected idle mode engine operation would be accepted and be workable, and from the standpoint that the low thrust operation of the engine might be required for orbital maneuvers. Consideration of the latter introduces the possibility of inclusion of the "autogenous" pressurization methods discussed in detail in Section 3.

(U) Based upon the "Accessibility Study" results produced in Section 6, the comparisons shown in Figure 7-1 were constructed. The results were somewhat surprising in that the autogenous systems showed little advantages with regard to having lower probabilities of failure (significantly lower for only one case). This is not readily apparent from examination of the subsystem schematics, since the helium systems are much more complex. Another interesting result is that the regulator modulated systems appear to be more satisfactory for reusable subsystem applications.

(U) A comparison of pressurization subsystems is presented in Table 7-4. Weight comparisons were previously presented in Section 3, Table 3-3.

Selected Pressurization Subsystem (U)

(C) The selected pressurization subsystem is as follows:

(1) Pressurization of the tanks prior to liftoff from a ground supply and subsequent pressurization and during ascent of the LH_2 tanks with GH_2 engine bleed and pressurization of the LO_2 tanks with GO_2 engine bleed.

(2) If the low thrust mode of engine operation is used for subsequent maneuvers, the autogenous pressurization system, operating entirely from engine bleed is selected; OR:

If the idle mode of engine operation, or a secondary propulsion subsystem is used, the pressurization must be provided from a pump liquid to gas conversion subsystem (which operates much in the same manner as an Integrated Attitude Control conversion subsystem).

PRECEDING PAGE BLANK-NOT FILMED.

CONFIDENTIAL

Table 7-4

REUSABLE LAUNCH VEHIC
COMPARISON OF PRESSURIZATION
(CONFIDENTIAL)

Identity	Compari			
	1	2	3	
Pressurization susbsystems	**Description:** Pre-press / Press LO_2 He O_2 LH_2 He H_2 **System:** 1. Cold He and heat exchanger 2. Engine bleed **Advantages:** 1. Positive prepressurization 2. Developed techniques 3. Lower helium storage weight than (2) **Disadvantages:** 1. Complexity of helium heater 2. High residual LO_2 weight	**Description:** Pre-press / Press LO_2 He O_2 LH_2 He H_2 **System:** 1. Amb-He 2. Engine bleed **Advantages:** 1. Positive prepressurization 2. Developed techniques 3. No helium heater required **Disadvantages:** 1. High helium storage weight 2. High residual LO_2 weight	**Description:** Pre-press / Press LO_2 He He LH_2 He H_2 **System:** 1. Cold He and heat exchanger 2. Engine bleed 3. Modulated valve control **Advantages:** 1. Positive prepressurization 2. Developed techniques 3. Lower residual gas weight 4. Large regulator not required **Disadvantages:** 1. Complexity of helium heater 2. Lower reliability	**Descriptio** Pr pr LO_2 H LH_2 H **System:** 1. Cold He exchang 2. Engine 3. Regulat **Advantages** 1. Positive surizati 2. Develop techniqu 3. High rel **Disadvanta** 1. Comple helium 2. Large r require

Table 7-4

E LAUNCH VEHICLE,
RESSURIZATION SUBSYSTEMS (C)

ONFIDENTIAL)

	Comparison Matrix			
	4	5	6	7
ress	Description: Pre-press / Press	Description: Pre-press / Press	Description: Pre-press / Press	Description: Pre-press / Press
He	LO_2 He He	LO_2 He He	LO_2 O_2 O_2	LO_2 O_2 O_2
H_2	LH_2 He H_2	LH_2 He H_2	LH_2 H_2 H_2	LH_2 H_2 H_2
eat ve	System: 1. Cold He and heat exchanger 2. Engine bleed 3. Regulated control	System: 1. Amb He 2. Engine bleed	System: 1. Autogeneous 2. Valve modulated	System: 1. Autogeneous 2. Regulated
es- l or	Advantages: 1. Positive prepressurization 2. Developed techniques 3. High reliability	Advantages: 1. Positive prepressurization 2. Developed techniques 3. No helium heater required	Advantages: 1. Fewer components 2. Large regulators not required 3. Leakage not important factor	Advantages: 1. Fewer components 2. Leakage not important factor 3. High reliability
lity	Disadvantages: 1. Complexity of helium heater 2. Large regulators required	Disadvantages: 1. High helium storage weight	Disadvantages: 1. New development requirements 2. Lower reliability	Disadvantages: 1. New development requirements 2. Large regulators required

2

PRECEDING PAGE BLANK-NOT FILMED.

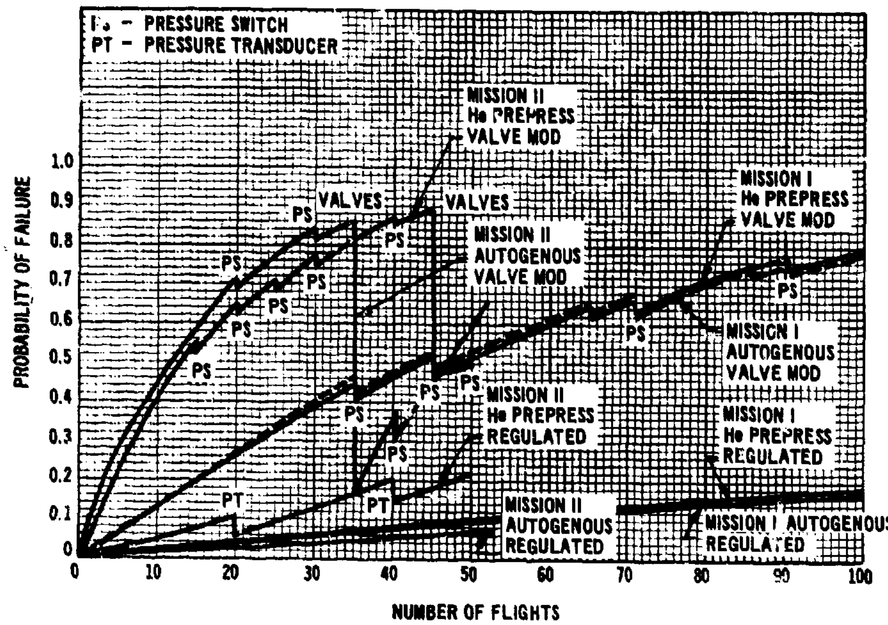


Figure 7-1 Comparison of Pressurization Subsystems (U)

7.2.3 Propellant Tank Tradeoffs (U)

(U) The distribution of propellants and the propellant tanks in the Reusable Launch Vehicles may be arranged in several possible configurations. The principal approaches are presented in Table 7-5. As may be determined by examination of this table, the principal tradeoffs are associated with storage of the orbital maneuver/retro propellant for long periods, necessity for multilayer insulation, and availability of retro propellant.

Selected Propellant Tank Arrangement (U)

(C) The selected propellant tank arrangement is to separate the orbital transfer, maneuver, and retro propellants from the ascent propellants. The larger ascent tanks would be insulated with foam type insulation and would not be required to store propellants in orbit. The small tanks containing the orbital transfer, maneuver, and

Table 7-5

REUSABLE LAUNCH VEHIC
COMPARISON OF PROPELLANT TANK A
(CONFIDENTIAL)

Identity	Functional and Technical Design Requirements	
		1
Propellant tanks	1. Containment of 49,982 lb propellant 2. Deorbit propellant requirements, 2000 lb 3. Orbit maneuver propellant requirements, 6300 lb 4. No aerodynamic maneuver capability required	Description: Storage of all required propell in main propellant tanks Advantages: 1. Simplification of subsysten 2. Less weight Disadvantages: 1. ΔV error could cause use (retro-propellant 2. Pressurization of large vol required 3. Propellant storage not effi(4. Additional cycles put on ma tank components 5. Multilayer insulation requi main propellant tanks

Table 7-5

ιE LAUNCH VEHICLE,
ΙPELLANT TANK ARRANGEMENTS (C)

ΟNFIDENTIAL)

Comparison Matrix		
1	2	3
ι: ιll required propellant ιpellant tanks	Description: Storage of required ascent and orbit maneuvering propellant in main propellant tanks. Separate retro-tank for reentry	Description: Storage of required ascent propellants in main tank. Separate tanks for orbit maneuvering and retro-propellant
ι: ιcation of subsystems ιeight	Advantages: 1. Retro-propellant always available 2. Smaller lines from retro-tank	Advantages: 1. Pressurization of large ullage not required for restart 2. Multilayer insulation not required on large tanks 3. Smaller lines from retro-tank
ιges: ιor could cause use of propellant ιrization of large volume ed ιlant storage not efficient ιnal cycles put on main ιmponents ιyer insulation required on ιropellant tanks	Disadvantages: 1. Additional weight, 300-400 lb more than (1) 2. More component than (1) 3. Less leakage allowable into or from tanks 4. Multilayer insulation required on main propellant tanks	Disadvantages: 1. Additional weight, 600-700 lb more than (1) 2. Retro-propellant could be more easily lost than (2)

retro propellants would be insulated with multilayer insulation and designed for storage of propellants up to 30 days.

7.2.4 Thermal Protection Tradeoffs (U)

(U) The thermal protection systems provided tradeoffs regarding several design features. These included:

- Thermal Protection for Propellant Tanks, Table 7-6
- Purging of Insulation, Table 7-7
- Thermal Protection of Feedlines, Table 7-8

(U) The information presented in Table 7-6, regarding the thermal protection of propellant tanks, concerns the selections previously discussed in paragraph 7.2.3, and the conclusions are related.

(U) The purging of the multilayer insulation systems during groundhold is a requirement to prevent liquification of air and icing within the insulation systems. The tradeoff comparisons presented in Table 7-7 are principally related to the necessity for purging during the reentry phase of flight.

(U) The thermal analyses presented in Section 4 indicated the problems associated with maintaining acceptable temperatures of the propellants in the feedlines during groundhold through the use of recirculation. Comparisons of thermal protections are presented in Table 7-8.

Selected Thermal Protection Subsystem Features (U)

(U) In accordance with the conclusions regarding the separation of propellants presented in paragraph 7.2.3, the selected approach to thermal protection of the propellant tanks is to employ foam type insulations on the ascent tanks and multilayer insulations on the orbital transfer, maneuver, and retro tanks.

Table 7-6

REUSABLE LAUNCH VEHICI
COMPARISON OF THERMAL PROTECTION FOR
(CONFIDENTIAL)

Identity	Co
	1
Thermal protection for propellant tanks	Description: Multilayer Insulation on both asc and maneuver/retro tanks Advantages: 1. Ascent tanks can be used for orbital storage for increased flexibility Disadvantages: 1. Higher insulation cost 2. Potentially higher boiloff

Table 7-6

LE LAUNCH VEHICLE,
PROTECTION FOR PROPELLANT TANKS (C)

ONFIDENTIAL)

Comparison Matrix	
1	2
	Description:
sulation on both ascent r/retro tanks	Foam insulation on ascent tanks and multilayer insulation on maneuver/retro tanks
	Advantages:
nks can be used for torage for increased y	1. Lower cost insulation on ascent tanks 2. Efficient storage
s:	Disadvantages:
sulation cost ly higher boiloff	1. Less flexibility in propellant storage

2

Table 7-7

REUSABLE LAUNCH VEHIC
COMPARISON OF THERMAL PROTECTION,
(CONFIDENTIAL)

Identity	Compar	
	1	
Thermal protection – purging of insulation	Description: GHe ground-hold vented insulation system. Atmospheric filled on reentry	Descriptio Ground-ho breathing system LO_2 – GN_2 ree LH_2 – GHe ree
	Advantages: 1. No purge gas system required	Advantage 1. Insulati 2. Helium
	Disadvantages: 1. Contamination of insulation with H_2O vapor 2. Possible air liquification	Disadvanta 1. Purge g weight 2. Separa system

Table 7-7

BLE LAUNCH VEHICLE,
RMAL PROTECTION, REENTRY PURGING (C)

(CONFIDENTIAL)

Comparison Matrix		
	2	3
vented n. At- on	**Description:** Ground-hold purged breathing insulation system LO_2 – GN_2 filled on reentry LH_2 – GHe filled on reentry	**Description:** Ground-hold purged breathing insulation system LO_2 – GHe filled on reentry LH_2 – GHe filled on reentry
system	**Advantages:** 1. Insulation protection 2. Helium saving	**Advantages:** 1. Insulation protection 2. Common purge gas storage
n of insu- 2O vapor	**Disadvantages:** 1. Purge gas system weight 2. Separate purge gas system	**Disadvantages:** 1. Purge gas system weight

2

Table 7-8

REUSABLE LAUNCH VE
COMPARISON OF THERMAL PROTECT

(CONFIDENTIAL)

Identity	Com	
	1	
Thermal protection of feedlines (principally for ground hold)	**Description:** Vacuum jacketing of feed lines. Multilayer insulation **Advantages:** 1. Improved control of propellant conditions during ground hold 2. Less recirculation required during ground ground hold 3. Satisfactory for filled feed lines in orbital operations **Disadvantages:** 1. Expensive to develop 2. Higher weight	**Descri** Foam i feed lin **Advanta** 1. Low vacu 2. Icing catic **Disadva** 1. Not fille orbi 2. High quir for grou

1

Table 7-8

ABLE LAUNCH VEHICLE,
HERMAL PROTECTION OF FEEDLINES (C)
(CONFIDENTIAL)

Comparison Matrix		
	2	3
ng of ltilayer	**Description:** Foam insulation of feed lines (purged)	**Description:** Multilayer insulation of feedlines
ntrol of onditions d hold ulation ing ground for filled orbital	**Advantages:** 1. Lower cost than vacuum jacketing 2. Icing and air liquification prevented	**Advantages:** 1. Satisfactory for filled feed lines in orbital operations
develop ht	**Disadvantages:** 1. Not satisfactory for filled feed lines in orbital operations 2. Higher flow-rates required than for (1) for recirculation on ground	**Disadvantages** 1. Higher cost than (2) 2. Very high flow-rates required for recirculation on ground

2

CONFIDENTIAL

(C) It was concluded that it is necessary to purge the multilayer insulation systems during reentry and landing. A single helium purging subsystem was selected for the purging of both the LO_2 and LH_2 tank insulations during reentry to simplify the subsystems.

(U) The thermal protection of the feedlines should be accomplished by vacuum jacketing with the inclusion of multilayer insulation. This is considered necessary for maintaining propellant conditions during groundhold.

7.2.5 Propellant Feedline Systems (U)

(U) A comparison was made of the possibilities of delivering Drop Tank propellants to the reusable tanks with the spacecraft, as compared to delivery of the propellant from both tanks to a manifold. The comparison is presented in Table 7-9.

(U) Since the Drop Tanks have different propellant pressures due to static head and also have pressure stabilization requirements, the pressures are not compatible with the reusable tanks.

Selection of Propellant Feedline System (U)

(U) The selected approach is to feed both the Drop Tank propellants and the Reusable Tank propellants into a common manifold to the engines.

7.2.6 Vent Subsystem Tradeoffs (U)

(U) The vent subsystem of a cryogenic propulsion subsystem is extremely critical in that it is not only related to operations, but also to safety. The vent system is an integral part of the pressure control system. During propellant fill operations, it is utilized to assist in preventing tank implosion. Two vent subsystem features were examined:

Table 7-9

REUSABLE LAUNCH VEHICLE, PROPELLANT

(CONFIDENTIAL)

Identity	Con
	1
Propellant feedline system	**Description:** Deliver drop tank propellant to reusable tanks **Advantages:** 1. Smooth change from drop to propellant tanks **Disadvantages:** 1. Higher residuals in lines from drop tanks and from reusable tanks 2. Additional weight 3. Drop tank and reusable tank pressure are not same

1

Table 7-9

ICLE, PROPELLANT FEEDLINE SYSTEM (C)
(CONFIDENTIAL)

Comparison Matrix	
1	2
n: op tank propellant to nks s: change from drop to ant tanks ges: residuals in lines from nks and from reusable onal weight ank and reusable tank re are not same	Description: Deliver drop tank propellants and reusable tank propellants to manifold Advantages: 1. Flexibility in tank pressures 2. Smaller lines from reusable tanks Disadvantages: 1. Change from drop tank flow to reusable tank flow

- (U) A separate venting subsystem for the Drop Tanks as compared to connection to the spacecraft vent subsystem (Table 7-10).
- (C) Employment of common LO_2 and common LH_2 vent and relief subsystems as compared to separate systems on each propellant tank (Table 7-11).

Selected Venting Subsystem Features (U)

(U) It was concluded that the vent lines from the drop tanks should be connected through disconnects to the spacecraft vent subsystem. This eliminated the loss of expensive vent and relief valves on the drop tanks.

(U) Each propellant tank should have its own vent and relief valve subsystem. Since the propellant tank conditions are never exactly the same, particularly during fill, the use of a common vent system would reduce the required flexibility.

7.2.7 Flight Disconnect Tradeoffs (U)

(U) As discussed in Section 6, flight disconnects present problems both in availability and in the development of sufficiently dependable components to assure proper actuation of all disconnects in the specified time intervals.

(U) A comparison of various alternate approaches to the disconnect of the feedlines and vent lines from the drop tank to the spacecraft is presented in Table 7-12. All three of the disconnect approaches examined require a shutoff valve on the liquid propellant feedlines since the disconnect leakages are so large.

Selected Flight Disconnect Method (U)

(U) The selected flight disconnect method was to close a valve on the spacecraft side of the feedlines and vent lines and explosively separate sections of line outboard of these valves. The section of line would be replaceable through the employment of a flange joint. It was determined that the necessary responses could be obtained and the technology is available.

Table 7-10

REUSABLE LAUNCH VEHICLE, COMPARISON OF DR
(CONFIDENTIAL)

Identity	Comp
	1
Vent system — drop tanks	<u>Description:</u> Vent lines from drop tanks connecte to spacecraft vent system <u>Advantages:</u> 1. Minimal hardware loss <u>Disadvantages:</u> 1. Disconnects required 2. Lines to vent system required

1

Table 7-10

E, COMPARISON OF DROP TANK VENTING (C)
CONFIDENTIAL)

Comparison Matrix	
1	2
ı:	**Description:**
from drop tanks connected ıft vent system	Vent lines from drop tanks perform as separate units
:	**Advantages:**
l hardware loss	1. No quick disconnects required
ges:	**Disadvantages:**
ıects required	1. Loss of vent and relief valve
o vent system required	2. Loss of GH_2 vent disconnect

PRECEDING PAGE BLANK NOT FILMED.

CONFIDENTIAL

Table 7-11

REUSABLE LAUNCH VEHICLE, COMPARISON OF SEPAR
(CONFIDENTIAL)

Identity	Cor
	1
Vent system – separate and common vent	Description: Common vent and relief valve for drop-tanks. Common vent and re valve for both reusable tank Advantages: 1. Saving of valves Disadvantages: 1. Individual tank pressures cann be controlled 2. Less implosion safety

1

Table 7-11

OMPARISON OF SEPARATE AND COMMON VENTS (C)
(CONFIDENTIAL)

Comparison Matrix	
1	2
on: vent and relief valve for both ks. Common vent and relief both reusable tank es: g of valves tages: idual tank pressures cannot ntrolled implosion safety	Description: Separate vent and relief valve for each drop tank. Separate vent for each reusable tank Advantages: 1. More positive pressure control 2. Implosion safety Disadvantages: 1. Additional weight 2. Additional component cost

Table 7-12

REUSABLE LAUNCH VEHIC
COMPARISON OF FLIGHT DISCC
(CONFIDENTIAL)

Identity	Compar	
	1	
Flight disconnects — feedlines and vent lines	**Description:** Feedlines and vent lines from drop tanks discon- nected during flight with quick-disconnects **Advantages:** 1. Minimum refurbishment **Disadvantages:** 1. Lower reliability 2. Loss of components	**Descriptio** Feedlines from drop nected dur explosive **Advantage** 1. High re **Disadvanta** 1. Refurbi require 2. Possibl valve d 3. Additio quirem lines

Table 7-12

LE LAUNCH VEHICLE,
N OF FLIGHT DISCONNECTS (C)

(CONFIDENTIAL)

Comparison Matrix		
	2	3
t lines iscon- it with ity ients	Description: Feedlines and vent lines from drop tanks disconnected during flight by explosive separation Advantages: 1. High reliability Disadvantages: 1. Refurbishment requirements 2. Possible shutoff valve damage 3. Additional valve requirements on vent lines	Description: Feedlines and vent lines from drop tanks disconnected during flight by searing separation Advantages: 1. High reliability Disadvantages: 1. Refurbishment requirements 2. Development requirements 3. Design load accuracy requirements 4. Specialized application 5. Additional valve requirements on vent lines

2

7.2.8 Propellant Utilization Subsystem Tradeoffs (U)

(U) The large propellant loadings of the Reusable Launch Vehicle indicate considerable emphasis should be placed on a propellant utilization subsystem. Through contacts with manufacturers and through examination of the subsystems, an attempt was made to formulate propellant utilization subsystems on the same basis to allow reasonably valid comparisons of the subsystems. This required assuring that the data processing, controls, etc., were carried to the same depth in each subsystem. The results of the "accessibility studies" from Section 6 are presented in Figure 7-2. As may be seen in this figure, the capacitance probes appear to have relatively high probabilities of failure as compared to the other subsystems.

(U) In Table 7-13, a comparison is presented of the various other factors influencing a choice of propellant utilization subsystem.

Selected Propellant Utilization Subsystem (U)

(U) On the basis of current development, it is necessary to select the capacitance probe for propellant utilization. However, the development of the RF Cavity sensing subsystem could possibly replace capacitance gaging.

7.2.9 Attitude Control Propellant Tradeoffs (U)

(U) As presented in Section 5, the attitude control propellant consumption for the Reusable Launch Vehicle is relatively large. Also, as discussed in paragraph 7.2.1, there exists the possibility that the attitude control subsystem may be part of a secondary propulsion subsystem for orbital transfer, maneuvers, and retro.

(U) From a preliminary examination of the storable propellant attitude control subsystems and the integrated attitude control subsystems, it would undoubtedly be concluded that there would be a higher probability of failure of the integrated attitude control subsystem, since it is a more complex subsystem. However, in the comparison shown in Figure 7-3, it may be seen that the integrated attitude control subsystem

CONFIDENTIAL

Table 7-13

REUSABLE LAUNCH VEHIC
COMPARISON OF PROPELLANT UTILIZA
(CONFIDENTIAL)

Identity	Co	
	1	2
Propellant utilization	Description: Capacitance gaging Advantages: 1. Developed subsystems 2. Good accuracy Disadvantages: 1. Low reliability 2. High weight (142 lb)	Description: RF cavity sensing Advantages: 1. Accuracy ±0.5% at cutoff (±2% full) 2. Few probes 3. Monitor losses Disadvantages: 1. Low reliability 2. Low weight (27 lb) 3. Development required

1

Table 7-13

LE LAUNCH VEHICLE,
PELLANT UTILIZATION SUBSYSTEMS (C)
CONFIDENTIAL)

Comparison Matrix		
2	3	4
n:	Description:	Description:
sensing	Nuclear gaging	Flowmeter
s:	Advantages:	Advantages:
cy ±0.5% at cutoff ll)	1. Reasonably reliable	1. Reasonably reliable
obes	2. Monitor losses	
r losses		
ges:	Disadvantages:	Disadvantages:
liability	1. Large number of installations	1. Not suitable for mixed liquid/gas flow
eight (27 lb)	2. Radiation	2. High weight (116 lb)
pment required	3. Moderate weight (93 lb)	3. Development required
	4. Development required	

2

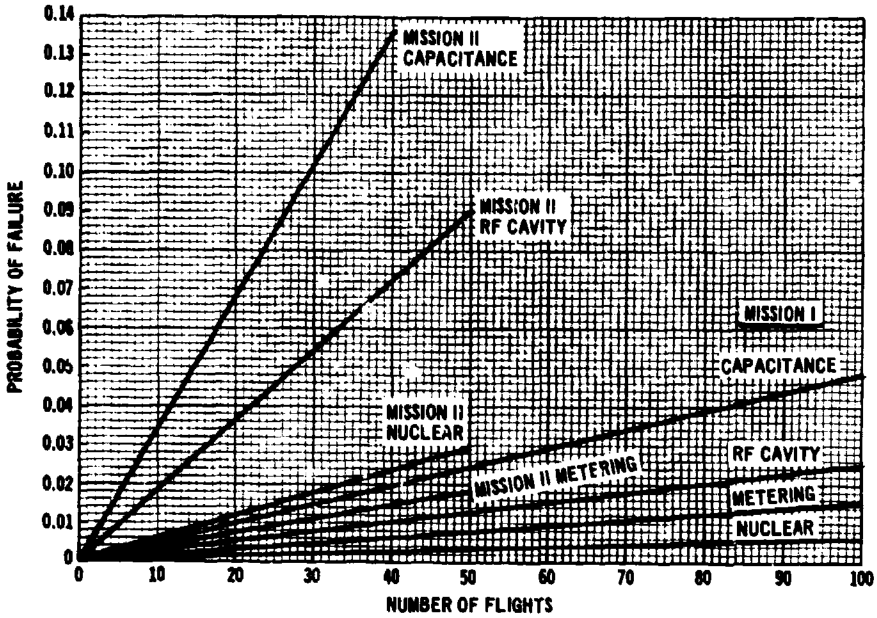


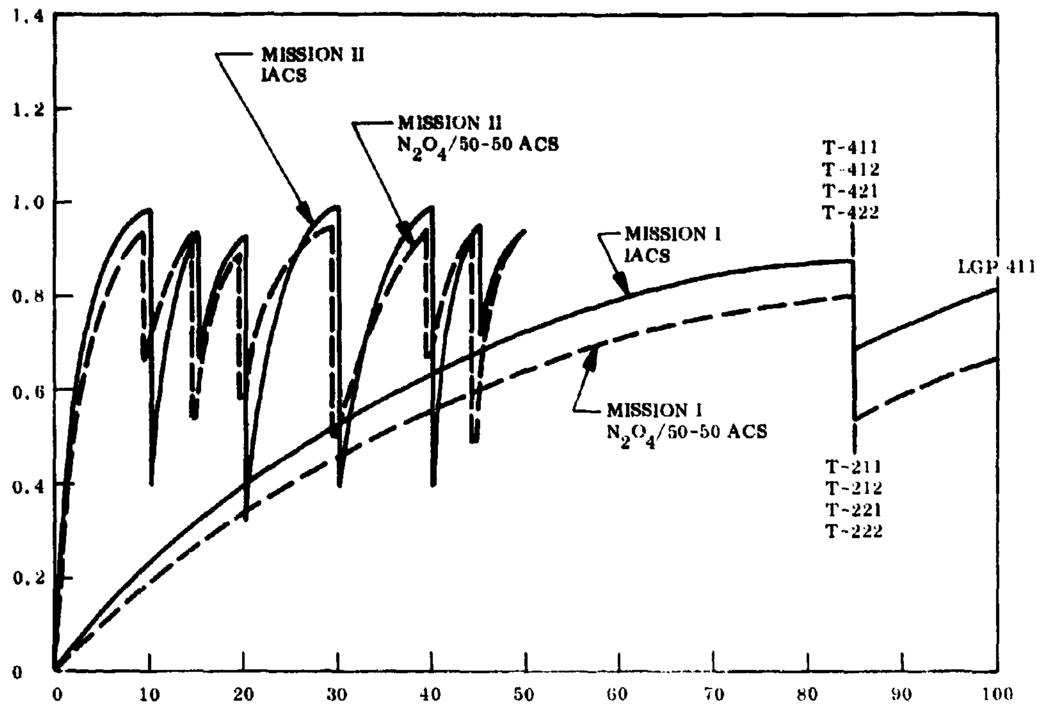
Figure 7-2 Comparison of Propellant Utilization Subsystems for the Reusable Launch Vehicle (U)

did not have a significantly higher probability of failure, but did require that more components be replaced. Components having limited lifetimes in the integrated attitude control subsystem were the liquid pumps, heat exchanger, two-way/three-way valves, and pressure switches.

(U) A comparison of the reaction control propellants is presented in Table 7-14. This comparison tended to indicate that the integrated attitude control subsystem has many advantages, one of the more important being a really significant increase in specific impulse. If this can be combined with a relatively low minimum impulse bit engine, then the system will be extremely attractive.

Selected Attitude Control Propellants (U)

(C) The selected attitude control propellants were oxygen and hydrogen. These provide the most flexibility for application in the Reusable Launch Vehicles.



	DAYS 10	15	20	30	40	45	50
Mission II ACS N_2O_4/50-50	T211 T212 T221 T222	CK201 CK202 TCC23 T213 T223	T221 T212 T221 T222	CK201 CK202 TCC23 T211 T213 T221 T222 T223	T211 T212 T221 T222	CK201 CK202 TCC23 T213 T223	T211 T212 T221 T222
Mission II IACS	T411 T412 T421 T422 PS411 PS412 LGP411 LGP412	T413 T423 TCC23 U413 U416	T411 T412 T421 T422 PS411 PS412 LGP411 LGP412 HBX411	T411 T412 T413 T421 T422 T423 TCC23 PS411 PS412 LGP411 LGP412 U413 U416	T411 T412 T421 T422 PS411 PS412 LGP411 LGP412 CK416 HBX411	T413 T423 TCC23 U413 U416 CK411 CK412	T411 T412 T421 T422 PS411 PS412 LGP411 LGP412

Figure 7-3 Comparison of Reusable Launch Vehicle Attitude Control Subsystems (U)

Table 7-14

REUSABLE LAUNCH VEHICI
COMPARISON OF ATTITUDE CONTROL

(CONFIDENTIAL)

Identity	Compar	
	1	
Reaction control propellant	Description: Integrated LO_2/LH_2 attitude control Advantages: 1. High specific impulse 2. Less propellant weight 3. Comparable reliability 4. May constitute secondary propulsion subsystem 5. May be integrated with power and EC Disadvantages: 1. System not developed 2. Accumulators normally required 3. Higher component replacement	Description: N_2O_4/50-50 attitude con Advantages: 1. Develope 2. Compara Disadvantag 1. Propellan consumpt 2. Propellan tanks

1

Table 7-14

BLE LAUNCH VEHICLE,
TTITUDE CONTROL PROPELLANTS (C)
(CONFIDENTIAL)

Comparison Matrix		
	2	3
H_2	**Description:** N_2O_4/50-50 attitude control	**Description:** Compound A/MHF-5 attitude control
npulse t liability ulsion ed ECS	**Advantages:** 1. Developed system 2. Comparable reliability	**Advantages:** 1. Higher specific impulse than (2) 2. Comparable reliability
loped or- nt	**Disadvantages:** 1. Propellant consumption 2. Propellant storage tanks	**Disadvantages:** 1. System not developed 2. Propellant consumption greater than (1) 3. Passivation problems

2

CONFIDENTIAL

7.3 CRYOGENIC SPACECRAFT (LF_2/LH_2) (C)

(C) The Cryogenic Spacecraft (LF_2/LH_2) did not present as many possible subsystem tradeoffs as the Reusable Launch Vehicle, since it has much less complex subsystems. Some of the tradeoff studies are unique to the Cryogenic Spacecraft and are not of general applicability to reusable vehicles.

7.3.1 Propellant Tank Configuration Tradeoffs (U)

(C) As presented in Section 3, and Appendix C, considerable attention was given to the analysis of the propellant tanks, since several shapes were under consideration which were not bodies of revolution or which were loaded in a lateral direction. These analyses did not indicate that severe design difficulties existed in the use of "segmented" type tanks, or in loading the tanks in the lateral direction. Manufacturing problems were recognized to be present in the "segmented" tanks. Tradeoff comparisons are presented in Table 7-15.

Selected Tank Configuration (U)

(C) Considering the desired flexibility in design for the utilization of propellant bay volumes, the segmented type of propellant tank is considered to be the best suited for the Cryogenic Spacecraft.

7.3.2 Pressurization Subsystem Tradeoffs (U)

(U) The pressurization subsystem presented an important tradeoff consideration. As was discussed in detail in Section 3, there are two major approaches to the pressurization of the Cryogenic Spacecraft:

- The "instant" start mode of pressurization, which keeps the tanks at engine start conditions at all times.
- The "normal" start mode of pressurization, which requires the tanks to be prepressurized prior to engine start.

PRECEDING PAGE BLANK NOT FILMED.

CONFIDENTIAL

Table 7-15

CRYOGENIC SPACECRAFT, COMPARISON OF PROPE

(CONFIDENTIAL)

Identify	Co	
	1	2
Propellant tank configurations	Description: Separate segmented tanks Advantages: 1. Flexibility in conforming to shapes Disadvantages: 1. Plumbing difficulties 2. More difficult to develop 3. Manufacturing problems	Description: Horizontal cylindrical Advantages: 1. Simplified tanks holding sufficient mission propella 2. Few manufacturing problen Disadvantages: 1. Limited flexibility

able 7-15

SON OF PROPELLANT TANK CONFIGURATIONS (C)
NFIDENTIAL)

Comparison Matrix		
2	3	4
indrical tanks holding mission propellant facturing problems s: exibility	Description: Maximum loading conforming tanks Advantages: 1. Maximum propellant loading Disadvantages: 1. Normally not required since vehicle maximum weight limits loading 2. More difficult to develop	Description: Maximum loading multitanks Advantages: 1. High propellant loading in simplified tanks 2. Few manufacturing problems Disadvantages: 1. Several systems required 2. Plumbing difficulties

(U) These two methods were analyzed in detail in Sections 3 and 6. The results of the "Accessibility Studies" conducted in paragraph 6.3, are presented in Figure 7-4. The results indicate that the "instant start" method of pressurization has a much lower probability of failure than the "normal start" method. This is apparent from the examination of the schematics in Section 3.

(U) A comparison of various points regarding the two pressurization methods is presented in Table 7-16.

Selected Pressurization Method (U)

(U) The "instant start" method of pressurization was selected as the method presenting the most attractive features, and a less complex subsystem.

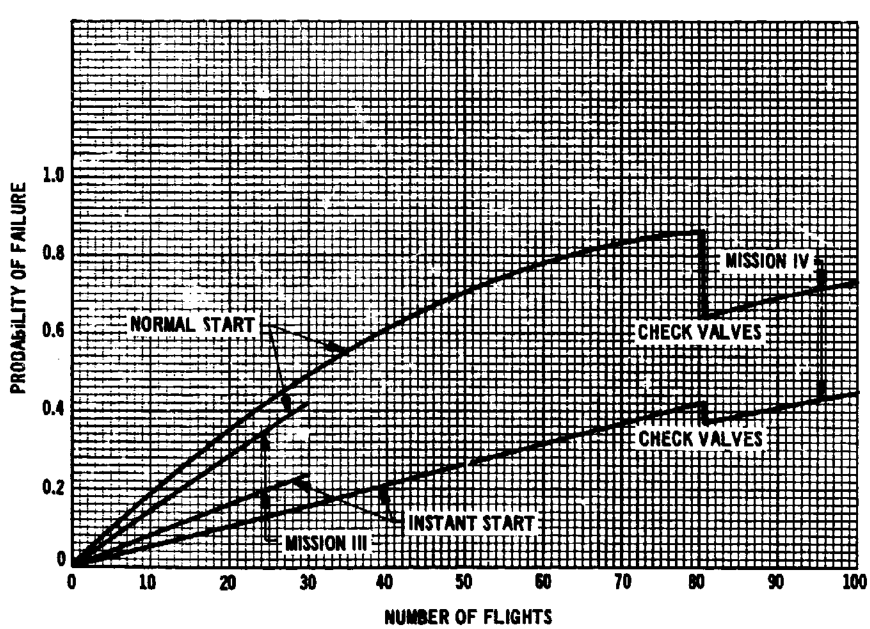


Figure 7-4 Comparison of Pressurization Methods for Cryogenic Spacecraft (U)

Table 7-16

CRYOGENIC SPACECRAFT, COMPARISON OF PRES

(CONFIDENTIAL)

Identity	Con
	1
Pressurization method	**Description:** Instant start **Advantages:** 1. Engine start ready at all times 2. Less probability of failure **Disadvantages:** 1. Thermal problems associated with filled propellant lines 2. Higher weight

Table 7-16

T, COMPARISON OF PRESSURIZATION METHODS (C)
(CONFIDENTIAL)

Comparison Matrix	
1	2
tion:	Description:
tart	Pre-pressurization. Normal start
ges:	Advantages:
ne start ready at all times	1. Less helium gas required
probability of failure	2. Developed approach
ntages:	Disadvantages:
mal problems associated filled propellant lines	1. Higher probability of failure
er weight	2. Complex helium heating system

7.3.3 Thermal Protection of Fluorine Tanks (C)

(C) It is very desirable that fluorine tanks be non-vented during groundhold and ascent, if at all possible. This can be accomplished by a nitrogen circulation cooling system to keep the fluorine at a suitable temperature, or by the use of a liquid nitrogen spray over the tanks, or by vacuum jacketing.

(C) In the thermal analyses presented in Section 4, attention was given to an investigation of the use of vacuum jacketed fluorine tanks in the Cryogenic Spacecraft. Since the fluorine tanks are relatively small, vacuum jacketing becomes feasible.

(U) A comparison of the advantages and disadvantages of each approach is presented in Table 7-17.

<u>Selected Fluorine Tank Thermal Protection</u> (C)

(C) Since the weight penalty is relatively small and the advantages in flexibility considerably increase, the vacuum jacketing of the fluorine tank was selected as the means of thermal protection.

7.3.4 Propellant Utilization Subsystem Tradeoffs (U)

(U) The large number of starts required for the performance of the Cryogenic Spacecraft missions requires that the propellant utilization subsystem be very accurate. The desired accuracy is higher than can be assured by present subsystems. A comparison of the failure probabilities of the various candidate propellant utilization subsystems is presented in Figure 7-5. The ranking of the subsystems is approximately as shown for the Reusable Launch Vehicles. The various considerations related to the selection of a subsystem are essentially the same as those presented in Table 7-13.

Table 7-17

CRYOGENIC SPACECRAFT, COMPARISON OF THERMAL PROTE

(CONFIDENTIAL)

Identity	Compa
	1
Thermal protection of fluorine tank	Description: Vacuum jacketed tanks with multilaye insulation Advantages: 1. Simplifies ground-hold problems 2. Contributes to nonvent system capability 3. LF_2 tanks relatively small Disadvantages: 1. Heavier weight 2. Difficult to use with segmented tanks

1

Table 7-17

OF THERMAL PROTECTION FOR FLUORINE TANKS (C)
ONFIDENTIAL)

Comparison Matrix	
1	2
ed tanks with multilayer	Description: Purged multilayer insulation and external cooling
ground-hold problems s to nonvent system relatively small	Advantages: 1. Less weight 2. Easy to install on segmented tanks
ight use with segmented	Disadvantages: 1. External cooling required during ground hold 2. Less positive system

2

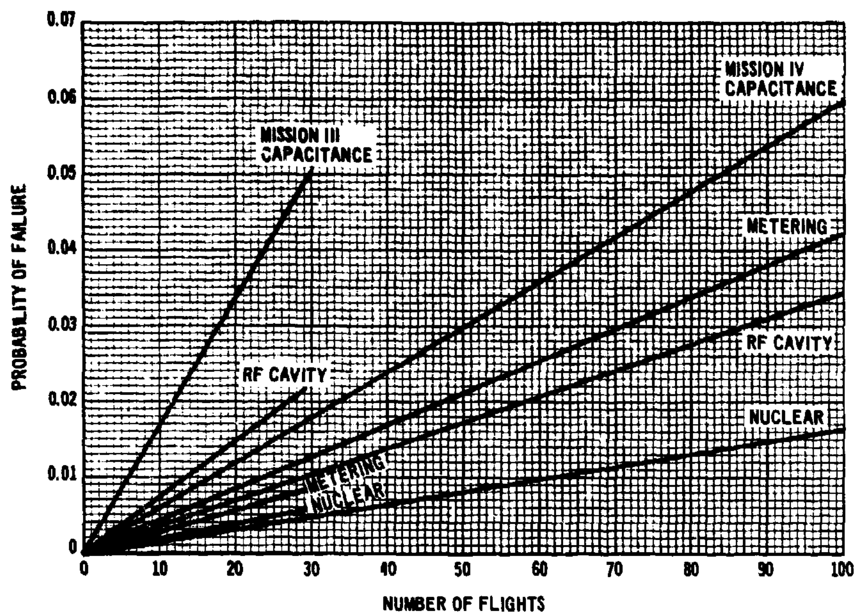


Figure 7-5 Comparison of Propellant Utilization Subsystem for the Cryogenic Spacecraft (U)

Selected Propellant Utilization Subsystem (U)

(U) Considering the present state of development of the various propellant utilization subsystems, the capacitance probe was selected based upon its advanced development status and known accuracies. The RF Cavity sensor offers the very attractive feature of a very small installation, and may replace the capacitance probe when the technology is developed.

7.3.5 Comparison of Attitude Control Propellants (U)

(U) The Cryogenic Spacecraft requires a considerable quantity of attitude control propellants in order to perform the required maneuvers. Also, the spacecraft propellant bay envelope is not attractive for the design of a storage system for attitude control propellants, because of the very limited available space.

(U) A comparison of the attitude control systems, generated in Paragraph 6.3, is presented in Figure 7-6. As indicated, the probability of failure of an integrated attitude control subsystem is only slightly higher than a storable propellant subsystem. Here again, though, the number of component replacements is relatively high. Maintenance is required in some cases every one or two flights.

(U) Other considerations related to selection of the attitude control propellants are presented in Table 7-18.

Selected Attitude Control Propellants (U)

(C) The selection of the attitude control propellants is a very difficult choice, considering the various factors involved. The N_2O_4/50-50 propellants were selected as the first choice. This choice was based upon consideration of the propellant consumption, storage, and problems associated with maintenance on the fluorine components in the integrated attitude control subsystems.

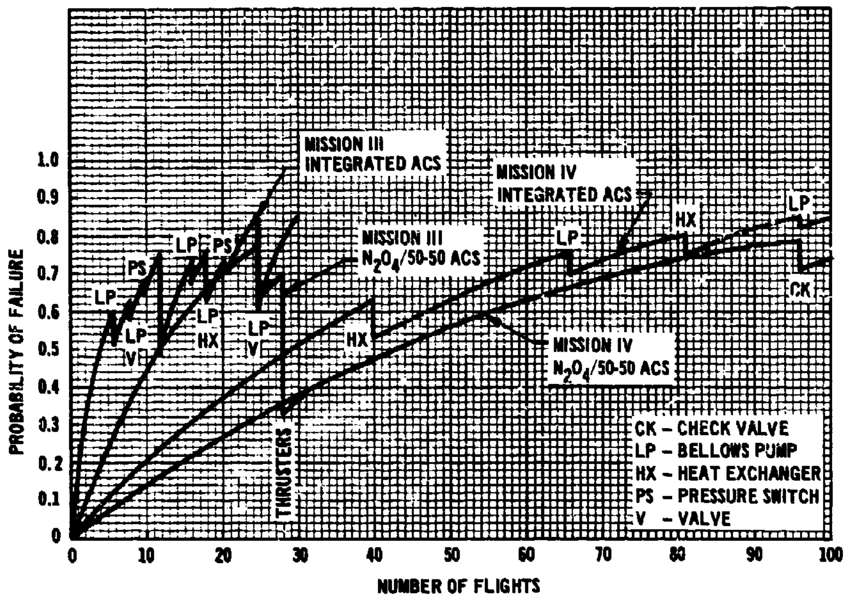


Figure 7-6 Comparison of Attitude Control Propellants for Cryogenic Spacecraft (U)

Table 7-18

CRYOGENIC SPACECRAF
COMPARISON OF ATTITUDE CONTROI
(CONFIDENTIAL)

Identity	Comp	
	1	
Reaction control propellants	Description: Integrated LF_2/LH_2 attitude control Advantages: 1. High specific impulse 2. Less propellant weight 3. Comparable reliability Disadvantages: 1. System not developed 2. Higher component replacement 3. Fluorine compatible systems 4. Passivation problems	Descriptio N_2O_4/50- attitude co Advantage 1. Develo 2. Compa reliabi Disadvant 1. Propell consum 2. Propell tanks

1

Table 7-18

OGENIC SPACECRAFT,
ATTITUDE CONTROL PROPELLANTS (C)
(CONFIDENTIAL)

Comparison Matrix		
	2	3
	Description:	Description:
LH_2	N_2O_4/50-50 attitude control	Compound A/MHF-5 attitude control
	Advantages:	Advantages:
impulse	1. Developed system	1. Higher specific impulse than (2)
ant	2. Comparable reliability	2. Comparable reliability
	Disadvantages:	Disadvantages:
eveloped	1. Propellant consumption	1. System not developed
onent	2. Propellant storage tanks	2. Propellant consumption greater than (1)
npatible		3. Passivation problems
problems		

7.4 STORABLE SPACECRAFT (N_2O_4/50-50) (C)

(U) As previously presented in this report, the Storable Spacecraft subsystem is relatively straightforward in design and operation. The possible propellant feedline and pressurization subsystems are limited to only small variations of those which have been presented.

7.4.1 Propellant Tankage Configurations (U)

(C) The high density of the N_2O_4/50-50 propellants, as compared to the cryogenic propellants, considerably reduce the storage problems associated with the limited propellant bay volumes. The total weight of the vehicle becomes the limiting factor in the amount of propellant which can be put into the vehicle, rather than the propellant bay volume.

(U) This added flexibility allows for the employment of more conventional tankage to advantage in the Storable Spacecraft. A comparison of the propellant tank configurations is presented in Table 7-19.

<u>Selected Tank Configurations (U)</u>

(U) Cylindrical tanks with $\sqrt{2}$:1 elliptical bulkheads were selected for the Storable Spacecraft. These conventional tanks are compatible with the available storage volumes and minimize costs and development problems.

7.4.2 Propellant Utilization Subsystem Tradeoffs (U)

(U) In the previous sections, various comparisons have been made of the propellant utilization subsystems. The Storable Spacecraft differs somewhat from the cryogenic spacecraft in that no problems exist in the feedlines relative to chilldown or gas flow in the initial phases of engine start. It is also desirable, of course, that the propellant utilization system have reliable operation. A comparison of the probabilities of failure for various subsystems is presented in Figure 7-7.

Table 7-19

STORABLE SPACECRA
COMPARISON OF PROPELLANT TANK

(CONFIDENTIAL)

Identity	Comp	
	1	
Propellant tanks for storable spacecraft	**Description:** Separate segmented tanks **Advantages:** 1. Flexibility in conforming to shapes **Disadvantages:** 1. Plumbing difficulties 2. More difficult to develop	**Descript** Separate tanks **Advantag** 1. Simpli holdin missio **Disadvan** 1. Limite

Table 7-19

ORABLE SPACECRAFT,
PROPELLANT TANK CONFIGURATIONS (C)

(CONFIDENTIAL)

Comparison Matrix		
	2	3
	Description:	Description:
ented	Separate cylindrical tanks	Conformed tankage
	Advantages:	Advantages:
n to shapes	1. Simplified tanks holding sufficient mission propellant	1. Maximum propellant loading
	Disadvantages:	Disadvantages:
lt to	1. Limited flexibility	1. Normally not required since vehicle maximum weight limits loading

2

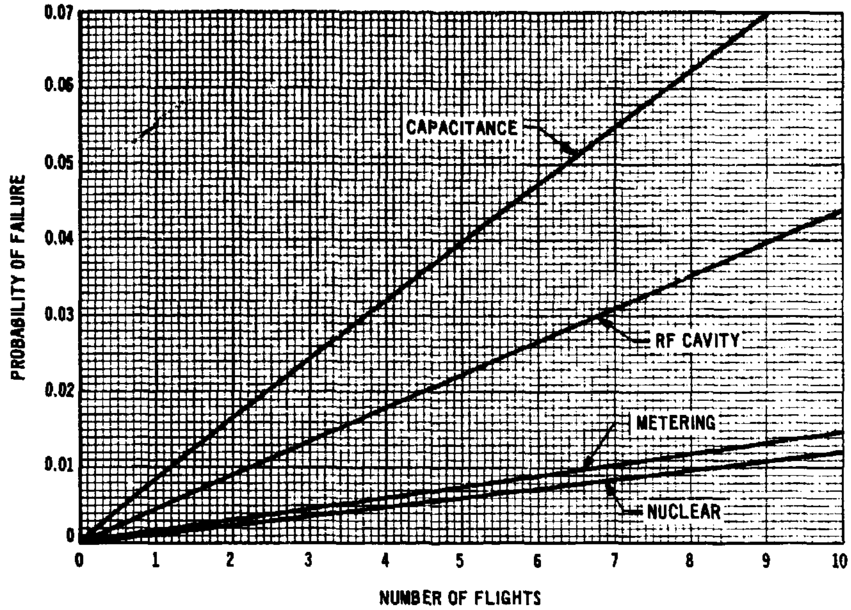


Figure 7-7 Comparison of Propellant Utilization Subsystems for the Storable Spacecraft (Mission IV) (U)

Selected Propellant Utilization Subsystem (U)

(U) The selected method for propellant utilization was the employment of a metering subsystem. This system produces a low probability of failure and has a relatively good accuracy. The propellant orientation and feedline system can be arranged so as to have liquid propellant in the meter at all times during flight. This subsystem is also applicable to the synergetic turn maneuvers.

7.4.3 Attitude Control Propellants Tradeoff (U)

(U) As in the case of the Cryogenic Spacecraft, the maneuvers of the Storable Spacecraft require considerable propellant consumption, and mission flexibility is desirable.

(U) A comparison of the integrated and non-integrated attitude control subsystems is presented in Figure 7-8. The probabilities of failure are very comparable, and the replacements are low for each subsystem. In Table 7-20, additional comparisons are made of various factors.

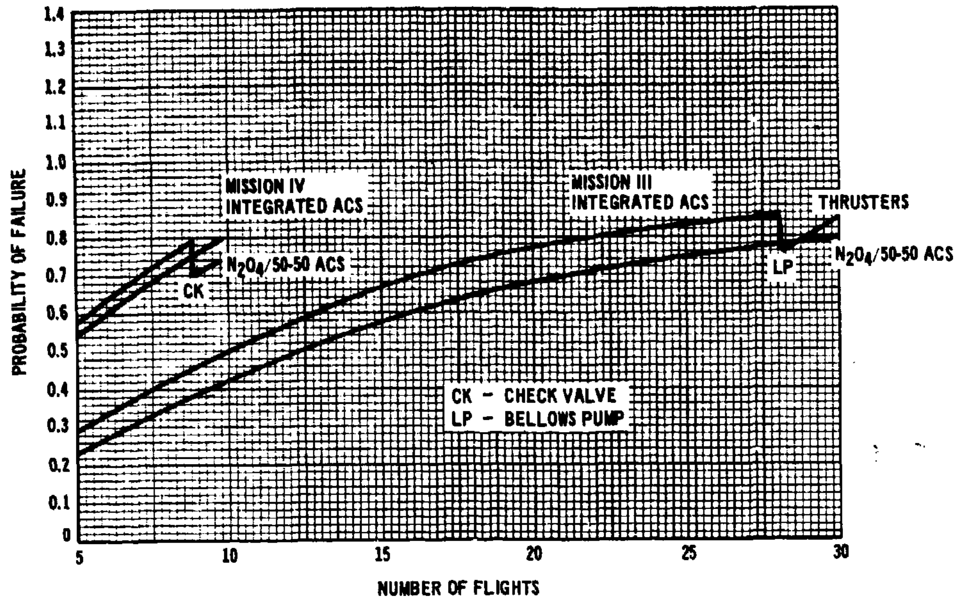


Figure 7-8 Comparison of Attitude Control Subsystems for the Storable Spacecraft (U)

Selected Attitude Control Propellants (U)

(C) The N_2O_4/50-50 Integrated Attitude Control subsystem was selected as the desired approach. The required flexibility is obtained through the use of a relatively simple system which requires little maintenance.

CONFIDENTIAL

Table 7-20

STORABLE SPACECRAFT,
COMPARISON OF ATTITUDE CONTROL P

(CONFIDENTIAL)

Identity	Compari	
	1	2
Attitude control propellant	Description: Integrated N_2O_4/50-50 attitude control Advantages: 1. Separate storage not required 2. Comparable reliability 3. Flexibility in propellant loading Disadvantages: 1. System requires development	Description: N_2O_4/50-50 attitude cont Advantages: 1. Develope 2. Compara reliabilit Disadvantag 1. Propellan consumpt 2. Propellan

1

Table 7-20

BLE SPACECRAFT,
TITUDE CONTROL PROPELLANTS (C)
ONFIDENTIAL)

Comparison Matrix		
	2	3
-50	**Description:** N_2O_4/50-50 attitude control	**Description:** Compound A/MHF-5 attitude control
pel-	**Advantages:** 1. Developed system 2. Comparable reliability	**Advantages:** 1. Higher specific impulse than (2)
	Disadvantages: 1. Propellant consumption 2. Propellant storage	**Disadvantages:** 1. System not developed 2. Propellant consumption greater than (1)

Section 8
ADVANCED TECHNOLOGY RECOMMENDATIONS (U)

(U) The principal objective of this study was to identify the technology requirements for reusable propulsion subsystems. The approach to accomplishment of this objective was to continuously examine each phase of the study effort to assure that technology requirements were identified at all levels of analysis and investigation. This continual identification and recording contributed to the entire study effort, in that it improved the validity of reusability and subsystem tradeoff examination through noting problem areas and also revealing where achievable extensions of technology would reduce the limitations on approaches to be considered.

8.1 OBJECTIVES AND SCOPE (U)

(U) Task 7 translated the reusable propulsion systems technology and component requirements derived throughout the study into recommendations for specific exploratory development programs. These programs are limited in scope to exploratory-development effort of the sort that must be completed in advance of a full-scale reusable-space-vehicle hardware development program. They are also limited in subject matter to those portions of the propulsion system exclusive of the main engine (engine development is in progress under the various AFRPL Advanced Development Programs). These recommended programs will make available to any reusable-vehicle development effort the critical technologies and components that pace the development of such vehicles.

(U) The task was performed in two steps; the recommendation and justification of programs, and the ranking of selected programs in priority order. The following paragraphs describe in detail the approach and the results obtained from these two steps.

8.2 RECOMMENDATION AND JUSTIFICATION OF PROGRAMS (U)

(U) The process of identifying potential exploratory development programs was carried on continuously during this study. Gaps in technology and in the availability of components were noted in almost every task of the study, but particularly in the following steps:

- Subsystem requirements analyses
- Studies of the suitability of existing components for reusable service
- Subsystem tradeoffs.

(U) In Task 7, all programs recommended in prior tasks were reviewed, and a systematic analysis of the results of these tasks was initiated to isolate any important technology programs not previously recommended. Once this step was completed, all recommended programs were written up and justified in outline form so as to compare the relative merit of the candidate programs. Criteria used in justifying the various programs center about the extent to which a program paces reusable vehicle development, and specifically whether it:

(1) Resolves a long-leadtime technology problem or a design tradeoff that must be evaluated before fullscale reusable vehicle development can commence, or

(2) Bears on one of the particularly sensitive factors of reusable vehicle system operation, such as inert weight and recurring cost (the latter being a function of complexity and refurbishment-cycle maintenance requirements).

(U) As a result of the program-justification analysis, a few candidate studies were omitted from the recommendation. These programs were judged to be worth performing as part of a fullscale vehicle development program, but not to be pacing items requiring resolution <u>before</u> such development begins. Typical examples are a pair of studies in which it was proposed to analyze in detail the propulsion system requirements for (1) performing the inspection mission and (2) executing the synergetic-turn maneuver. Such efforts would routinely be incorporated into the analytical phase of any reusable-vehicle development program involving these propulsive maneuvers, but their resolution cannot be considered critical to reusable propulsion system evolution.

(U) In all, some 21 programs were finally recommended. In reviewing these programs, it became apparent that they fall into three broad categories: Advanced Technology, Engineering Development (or Engineering Improvement), and General Programs. Details of the selected programs in these categories are presented in the following subsections. Note that the schedules and costs shown for all of these recommended programs are rough-order-of-magnitude estimates only. The actual schedules and costs will depend on such factors as the detailed statement of work, the amount of existing test apparatus available, and the number and type of analytical tools already developed by the contractor.

8.2.1 Advanced Technology Programs (U)

(U) Advanced technology programs were construed to be those that explore completely new fields of technology (e.g., autogenous pressurization) or hitherto undeveloped aspects of a relatively well explored field (e.g., thermal protection of reusable cryogenic vehicle tankage).

(U) The 11 advanced technology programs include disciplines related exclusively to the problems of reusable vehicles, such as leakage detection and the replacement of components, as well as technologies common to both expendable and reusable space vehicles (e.g., vent-free ground hold of oxidizers).

(U) The recommended Advanced Technology programs are described in the following pages.

IDLE MODE VS. LOW-THRUST PUMPED MODE FOR ORBITAL MANEUVERS (U)

PURPOSE (U)

(C) The purpose of this program is to evaluate a tradeoff involving the propulsion system operating mode for orbital maneuvering with cryogenic reusable space vehicles. This tradeoff compares idle mode operation (low thrust with engine turbopumps inoperative) against pump-fed low-thrust operation for orbital maneuvers such as orbit transfer, plane change, rendezvous, and similar low V operations. The principal advantages of the idle mode of operation are believed to be the possible savings in cooldown propellants. The evaluations should consider both the vehicle and engine factors related to idle mode operation.

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 1A for a listing of vehicle-related studies of low-thrust modes for cryogenic propulsion systems.

SCOPE OF WORK (U)

(U) Analyze idle mode operation for the VTOHL launch vehicle and cryogenic FDL-5 propulsion systems. The investigations will include studies of the engine factors as well as the vehicle considerations. Determine the temperature, pressure, and quality of propellants delivered to the engine in such a mode and predict engine performance levels and requirements placed on the vehicle subsystems.

(U) Perform small scale experimental programs as needed to substantiate the analyses. Formulate reusable-vehicle propulsion system designs, based on the idle mode operation.

(U) Analyze pumped-low-thrust operation for the reference vehicles. Include in the analysis a secondary tradeoff of techniques for inflight cooling of the feedlines (which is required in the pumped mode), considering the following approaches:

- Keeping feedlines full of liquid between firings and using a thermal conditioning unit to cool the liquid
- Keeping the lines empty before firings and using a circulating pump to chill the lines before engine start

(U) Formulate reference propulsion system designs based on the pumped-low-thrust mode of operation.

(C) Compare the idle mode and pumped mode on the basis of their weight, performance, complexity, and cost for each vehicle. The effects on engine design and development should be evaluated.

(C) Formulate a test plan to incorporate idle mode feasibility demonstrations in the Project 2 and Project 3 engine Advanced Development Programs (ADPs). Provide estimates of program cost and schedule effects.

ESTIMATED FACILITY REQUIREMENTS (U)

Facilities: (No major facilities required in this phase)

Schedule: 9 months

Funding: $150,000

JUSTIFICATION (U)

(C) This program resolves a major design tradeoff for both the VTOHL launch vehicle and the cryogenic FDL-5 spacecraft. The design of the space shuttle vehicle propulsion system is dependent upon the desirability and acceptability of the unpumped idle engine operational mode. The program also has a major influence on the Project 2 and Project 3 engine ADPs.

(C) Based upon the cooldown and specific impulse information, the potential saving in propellants for orbital operations for the idle mode over the low-thrust mode is slightly in excess of 10,000 lb for the VTOHL vehicle Mission II profile.

AUTOGENOUS PRESSURIZATION VS PREPRESSURIZATION (U)

PURPOSE (U)

(U) The purpose of this program is to evaluate a tradeoff comparing prepressurization against autogenous pressurization (use of bleed gas from an idling engine to attain full-thrust pressure levels) for cryogenic propulsion systems on reusable space vehicle. The program will consider the effects on both the vehicle subsystems and the engine design from the use of autogenous pressurization.

PRIOR PROGRAMS (U)

(U) No vehicle-related development has been completed in the field of autogenous cryogenic pressurization systems. See Appendix A, Section 2 for a list of exploratory development programs in the general field of cryogenic pressurization technology.

SCOPE OF WORK (U)

(U) Analyze the use of an autogenous pressurization system on a VTOHL launch vehicle and the cryogenic FDL-5 spacecraft as compared to conventional prepressurization techniques. Calculate the temperature and pressure histories for the overall vehicle propulsion systems to determine performance levels and verify the feasibility of the autogenous pressurization cycle for these applications. Formulate propulsion system designs based on autogenous pressurization for the reference vehicles, and evaluate the weights, complexity, reliability, etc.

(C) Perform analyses of helium prepressurization of the same model systems as examined for the autogenous approach. Design propulsion systems based on helium prepressurization for the reference vehicles. Compare the autogenous and the prepressurization concepts on the basis of relative weight, performance, reliability, and cost.

(C) Examine the effects upon the engines resulting from the inclusion of an autogenous pressurization capability. Formulate a test plan to incorporate autogenous pressurization system demonstration in the Project 2 and Project 3 ADPs. Produce an evaluation of the effects on the engine schedules and costs as a result of the inclusion of autogenous pressurization.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	(No major facilities in this phase of program)
Schedule:	12 months
Funding:	$200,000

JUSTIFICATION (U)

(C) This program resolves a significant design tradeoff for both the VTOHL launch vehicle and the cryogenic FDL-5 spacecraft. The outcome of the program also has a significant influence on the Project 2 and Project 3 engine ADPs.

(U) The use of an autogenous pressurization cycle permits elimination of the helium prepressurization system (helium tanks, lines, valves, regulators, etc.). The elimination of this subsystem would result in significant reduction in system complexity and possible reduction in cost. The potential reduction in the VTOHL vehicle pressurization system weight penalty with the autogenous cycle ranges from 100 to 500 lb.

OXYGEN/HYDROGEN INTEGRATED ATTITUDE CONTROL SYSTEMS (C)

PURPOSE (U)

(C) The purpose of this program is to develop a complete integrated attitude control system (comprising fluid removal unit, thermal conditioning system, plumbing, and thrusters) that is capable of operating with hydrogen and oxygen extracted from the main propellant tanks of a reusable space vehicle. This integrated attitude control system must be designed to the special requirements of reusable-vehicle service.

PRIOR PROGRAMS (U)

(U) Appendix A, Section 3 lists prior programs conducted in the general field of cryogenic attitude control systems.

SCOPE OF WORK (U)

(U) Establish the requirements for the integrated attitude control system for typical missions, and interpret these into specific component performance specifications.

(U) Analyze the particular design problems associated with the application of an integrated, cryogenic ACS on reusable vehicles, with special emphasis on the following:

- Propellant acquisition over the complete mission profile, including synergetic maneuvering
- Extended service life
- Ease of inspection, repair, and replacement

(C) Conduct component tests necessary to provide the required technological information for design assurance and parametric data. Design a flight weight system and fabricate a prototype for installation with LH_2 and LOX test tanks. Operate the system in simulated flight environments under the required operating conditions. The tests should verify component performance and the performance of the integrated system. Sufficient tests should be performed to obtain response information, determine component lifetime, assure reliability, and evaluate maintainability.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Space environment simulator with ACS altitude-firing duct
Schedule:	24 months
Funding:	$750,000

JUSTIFICATION (U)

(U) Integrated attitude control systems extend the flexibility of cryogenic vehicles through increasing available propellant. Also, the expected resultant specific impulse from the cryogenic attitude control system will be significantly higher than current storable systems. This program resolves this major long-lead technology alternative for the VTOHL launch vehicle, and the cryogenic and storable FDL-5 spacecraft.

REDUCING RESIDUAL AND TRAPPED LIQUID PROPELLANTS (U)

PURPOSE (U)

(C) The purpose of this program is to define and demonstrate techniques to reduce the amount of residual LOX and LH_2 remaining in the VTOHL launch vehicle after engine cutoff. This program will emphasize utilization of feedline propellants.

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 1B for a listing of prior programs in the general area of residual cryogenic propellant behavior.

SCOPE OF WORK (U)

(U) The program will involve analyses and testing. Analyze the behavior of residual and trapped propellants in the VTOHL launch vehicle. Determine the behavior of the liquid/vapor interface after pullthrough. Investigate the flow characteristics in feedlines after pullthrough. Conduct laboratory scale tests to verify the analytical predictions.

(U) Devise techniques to minimize the residuals, including instrument improvements. Investigate use of improved level sensing devices, such as nuclear and optical sensors to sense shutoff conditions in the feedlines.

(U) Fabricate a scale model of a typical tank/feedline arrangement with the selected residual control system. Conduct draining and depletion tests with LH_2 and LOX. Measure the quality of fluid at the simulated engine inlet. Measure the quantity of propellants remaining after shutdown.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Cryogenic test cell
Schedule:	12 months
Funding:	$250,000

JUSTIFICATION (U)

(U) Residuals present one of the major potential weight savings in reusable vehicles. Residual controls could effect a weight saving of 6000 lb of residuals for the VTOHL launch vehicle. The large feedline volumes in the space shuttle make utilization of these residuals desirable.

LIQUID SEALING OF VALVES AND FEEDTHROUGHS (U)

PURPOSE (U)

(U) The purpose of the program is to explore the feasibility of using continuous contact with liquid propellant as a sealing technique to reduce the loss of helium pressurant and propellant gases through valves and feedthroughs in the propellant tanks and lines of reusable space vehicles.

PRIOR PROGRAMS (U)

(U) No prior programs are known to have been conducted in this field. See Appendix A, Section 7A for a listing of prior programs in the general area of surface tension device technology.

SCOPE OF WORK (U)

(U) Formulate concepts for the liquid sealing techniques and analyze the theoretical feasibility of the liquid sealing techniques.

(U) Explore design problem areas such as methods or holding the liquid contact. Consider the use of gallery-type capillary liquid orientation devices.

(U) Conduct laboratory scale tests to measure leak rates through typical valves and feedthrough connectors with and without liquid contact. Fabricate models of typical liquid orientation devices and verify their performance in drop tower tests.

(U) Calculate complete propulsion system weights with and without liquid sealing devices, and including the effects of leakage.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Drop tower
Schedule:	12 months
Funding:	$150,000

JUSTIFICATION (U)

(U) The valve leakage problems in reusable vehicles are a potential major consideration. Liquid sealing possibly may represent a technology advancement to reduce gas leakage. This program could produce basic sealing data.

(C) Allowable gas leakage from the reusable launch vehicle could be as low as 3 scc/min from the small oxygen tanks and as low as 50 scc/min from the hydrogen tanks for helium pressurized systems. Also, considering the high gas leakage from large valves, the allowable leakages from the large tanks (LO_2 600 sccm max, LH_2 6000 sccm max) represent improvements over the capabilities of most large valves.

LEAKAGE DETECTION TECHNIQUES FOR REUSABLE PROPULSION SYSTEMS (U)

PURPOSE (U)

(U) The purpose of this program is to develop and demonstrated improved techniques for monitoring and locating leakage in the liquid propellant systems of reusable space vehicles. An objective will be to develop an external measuring system if possible.

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 1C, for a listing of prior programs in the related area of liquid propellant system leakage.

SCOPE OF WORK (U)

(U) Examine available approahces and conduct any tests necessary to determine the applicability and accuracy of present methods. Propulsion subsystem designs will be examined to develop sequenced checkout procedures to determine the existence and location of leakage. Evaluate advanced flaw-detection techniques such as the use of Krypton 85 gas.

(U) Fabricate a liquid propellant flow loop using typical space vehicle valves, lines and connections. Establish standardized leak rates in individual components before installing them in the test loop.

(U) Install one or more selected leakage detection devices and evaluate their efficiency under operating conditions (multiple cycles of propellant flow). Test for leakage using both the selected systems and conventional detection equipment (mass spectrometers, etc.).

(U) Engage in refinement of instruments and techniques to increase accuracy, reliability, etc.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities: Hazardous Test Cell
Schedule: 9 months
Funding: $250,000

JUSTIFICATION (U)

(U) The maintenance and rapid turnaround requirements of reusable vehicles necessitate rapid and accurate methods of detecting and monitoring leakage. Rocket powered vehicles have considerably more requirements in this respect than aircraft. Presently employed methods do not effectively locate leaks. The accurate measurement of leakage flow rates is also difficult.

THERMAL INSULATION FOR REUSABLE VEHICLE CRYOGENIC TANKS (U)

PURPOSE (U)

(U) The purpose of this program is to develop a thermal protection system (typically: insulation, purge bags, and tank supports) suitable for protecting cryogenic tanks over the complete mission environment of reusable space vehicles, namely; ground hold, launch, ascent, space flight, synergetic maneuvers, and reentry.

PRIOR PROGRAMS (U)

(U) No programs have been conducted in this specific field. However, extensive work has been done in the development of thermal protection systems for cryogenic space vehicles and some work has been completed in the development of thermal protection systems for cryogenic hypersonic vehicles. See Appendix A, Section 4 for a listing of this prior work.

SCOPE OF WORK (U)

(U) Analyze promising approaches to the thermal protection of cryogenic tanks on reusable space vehicles. Consider, in particular, the requirement for an insulation "breathing" system to maintain positive pressure in the purge bag during all atmospheric phases of flight. Conduct laboratory tests and small scale environmental tests to develop the materials and material systems necessary for the required application.

(U) Select the most promising concept and perform a detail design of this system. Fabricate a large scale test article comprising a liquid hydrogen tank (5 feet in diameter, or larger), the selected thermal protection system, and a segment of vehicle outer structure.

(U) Conduct a flight simulation in which the test apparatus, fully loaded with LH_2, is subjected to a sequence of environments paralleling those of an actual mission:

- Ambient pressure and temperature (ground hold)
- Vibration and acoustic excitation (launch)

(U)
- Rapid depressurization and simulated heating rates (ascent)
- Vacuum, simulated radiant heating, and cold-wall heat sink (space flight)
- Thin atmosphere (synergetic maneuvers)
- Increasing pressure and simulated heating (reentry)

(U) The tests will be performed for a sufficient number of cycles to determine the repeatability of the insulation systems. Possible means of deterioration and change in properties will be investigated. Maintainability studies will be performed.

ESTIMATED SOURCE REQUIREMENTS (U)

Facilities:	Flight environment simulator capable of reproducing the full flight environment and safely accommodating the LH_2 tank. Special environment-simulation equipment required includes a vacuum chamber, steam ejectors for rapid pumpdown, backfilling controls for low pressures, heat lamps (and possibly a solar simulator), cold wall, shaker, and acoustic generator
Schedule:	18 months
Funding:	$600,000

JUSTIFICATION (U)

(U) The reusable vehicles present unique problems in propellant storage, requiring reusable and maintainable insulation. The reentry phase of flight presents unique requirements for multilayer insulation in that the vacuum in the insulation must be refilled with gas upon reentry, resulting in the necessity for a "breathing" insulation system.

REPLACEMENT OF BRAZED AND WELDED CONNECTIONS (U)

PURPOSE (U)

(U) The purpose of this program is to develop and verify minimum-contamination techniques for the opening and resealing of brazed or welded plumbing lines on reusable space vehicles. The program will be principally experimental.

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 5A for a list of prior programs in the related areas of tube joining and contamination control.

SCOPE OF WORK (U)

(U) Typical propulsion subsystem plumbing concepts will be prepared to provide standard specimens for investigation.

(U) Analyze the nature, extent, and sources of contamination that arise from cutting into and resealing brazed/welded plumbing lines.

(U) Conduct experiments to determine the contamination from the required operations.

(U) Develop advanced low-contamination techniques for cutting, welding and brazing of lines. Fabricate samples to verify the chosen techniques, and conduct sufficient tests to prove the acceptability of the techniques.

ESTIMATED RESOURCE REQUIREMENTS (U)

<u>Facilities:</u> Tube joining equipment – hazardous test cell.
<u>Schedule:</u> 12 months
<u>Funding:</u> $200,000

JUSTIFICATION (U)

(U) Reusable propulsion subsystems will require periodic replacement of components through a predetermined maintenance schedule or component failures. It is desirable that brazed and welded connections be employed to the maximum extent to reduce leakage and increase reliability. Contamination during component replacement is considered a major potential problem.

FRACTURE MECHANICS IN LIQUID PROPELLANT TANKAGE (U)

PURPOSE (U)

(U) The purpose of this program is to establish key parameters related to the fracture mechanics of liquid propellant tank materials when exposed to extending loading conditions in contact with typical reusable-vehicle propellants.

PRIOR PROGRAMS (U)

(U) Key prior programs related to the structural characteristics of liquid propellant tankage materials are listed in Appendix A, Section 6A.

SCOPE OF WORK (U)

(C) Conduct mechanical-properties tests of candidate tank materials (aluminum and titanium alloys). Use notched and unnotched specimens of base material and weldments. Conduct tests in the expected environments of reusable vehicles:

- Extended cyclic loading
- Exposure to the liquid propellants of interest (LH_2, LF_2, LOX, N_2O_4, 50-50)

(U) On the basis of test results, calculate the threshold stress intensity factor (Initial Stress Intensity Factor/Plane-Strain Fracture Toughness) for each tank material in each appropriate propellant.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Structural test laboratory with capability to test specimens immersed in cryogenic and hazardous propellants
Schedule:	18 months
Funding:	$200,000

JUSTIFICATION (U)

(U) Existing fracture mechanics data are not available to the exent of allowing establishment of sufficiently accurate design allowables for pressurized systems employed in reusable vehicles. It is not considered practical nor desirable to conduct any tank pressure tests as a part of routine or periodic maintenance. Therefore, the tanks and plumbing must be designed for the lifetime of the vehicle. Using present data for LH_2 and LO_2, to establish design allowables may impose either an undue penalty on the vehicle weights or result in unacceptable factors of safety.

SURFACE TENSION CHARACTERISTICS OF LIQUID PROPELLANTS (U)

PURPOSE (U)

(U) The purpose of this program is to determine experimentally the ϕ coefficient (Actual Capillary Support/Theoretical Capillary Support) for the propellants of interest to reusable space vehicles so that surface tension devices can be designed for these vehicles.

PRIOR PROGRAMS (U)

(U) No programs have been conducted in this specific field. See Appendix A, Section 7A for a listing of prior programs in the general area of surface tension devices can be designed for these vehicles.

PRIOR PROGRAMS (U)

(U) No programs have been conducted in this specific field. See Appendix A, Section 7A for a listing of prior programs in the general area of surface tension device technology.

SCOPE OF WORK (U)

(C) Conduct a search of the literature for data on the surface tension characteristics of LF_2, LOX, LH_2, N_2O_4, 50-50, MMH, ClF_5, MHF-5.

(C) Determine propellants for which capillary-support characteristics data are required and perform laboratory testing to fill the gaps. Calculate the ϕ coefficients based on the test results.

(U) Compile a handbook of surface tension characteristics for liquid propellants.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities: Fluid dynamic laboratory

Schedule: 9 months

Funding: $150, 000

JUSTIFICATION (U)

(U) Propellant orientation is required both for the multistart missions of the reusable vehicles and for integrated attitude control systems. Basic data is desirable to assist in the design of these devices.

GROUND-HOLD VENT-FREE OXIDIZER SYSTEM (U)

(C) The purpose of this program is to identify and demonstrate the most promising techniques for maintaining reusable-space-vehicle cryogenic oxidizers (LOX and especially LH_2) in a nonvented condition during prelaunch ground hold.

PRIOR PROGRAMS (U)

(U) No programs have yet been conducted in this field.

SCOPE OF WORK (U)

Analyze promising vent-free oxidizer systems including:

- LN_2 spray
- Intrastage purge with inert gas
- Vacuum jacketing

(U) Compare the systems on the basis of weight, performance, complexity, maintainability, and cost, and select a candidate system for tes'

(C) Fabricate the prototype system and install it on an LF_2 tank (of 5 feet diameter or larger) that is suspended in an outer load-carrying shell. Fill the tank with LH_2 and operate the vent-free system. Monitor tank pressure and temperature profiles over a typical prelaunch hold span to verify proper system operation.

ESTIMATED FACILITY REQUIREMENTS (U)

(C) Facilities: Liquid Fluorine Test Facility
Schedule: 21 months
Funding: $300,000

JUSTIFICATION (U)

(U) The prevention of LF_2 venting during ground hold and ascent is considered desirable for purposes of safety and simplification of operations. This is considered possible through effective cooling of the propellant tanks.

8.2.2 Engineering Development Programs (U)

(U) In categorizing the recommended programs, "engineering development" was defined as including those programs in which an existing technology or component is extended to meet the requirements of some particular reusable-vehicle application.

(U) The 7 selected engineering development programs are described on the following pages.

MINIMUM-IMPULSE-BIT ACS THRUSTER (U)

PURPOSE (U)

(U) The purpose of this program is to develop an attitude control system (ACS) thruster assembly for reusable vehicles that produces appreciably lower total impulse in minimum-bit pulses than current designs. Such a thruster, in limit-cycle operation, expends less propellant per firing cycle and reduces the total number of cycles per mission.

PRIOR PROGRAMS (U)

(U) No exploratory development programs are known to have been conducted in this specific field.

SCOPE OF WORK (U)

(C) The investigation will be concerned with thrust chambers of 300-lb thrust or greater. Explore design approaches which lower minimum impulse-bit. Particular emphasis should be upon improved valve response rates and reduction of post-shutoff flow. The propellants for exploratory investigations may be N_2O_4/MMH. Advanced studies should include oxygen/hydrogen propellants.

(U) Fabricate a working prototype of the selected thruster design using existing hardware wherever possible to reduce costs. Conduct hot firing tests with the prototype to verify projected performance levels.

ESTIMATED RESOURCE REQUIREMENTS (U)

<u>Facilities:</u> Captive firing test cell
<u>Schedule:</u> 24 months
<u>Funding:</u> $600,000

JUSTIFICATION (U)

(U) The use of this thruster permits a weight saving as well as a reduction in the number of cycles per mission (thus increasing time between replacement) for all of the reusable vehicles under consideration. Maximum weight savings in ACS propellant for these vehicles with the minimum-impulse-bit thruster are as follows:

1-1/2 Stage VTOHL	Cryogenic FDL-5	Storable FDL-5
3640 lb	430 lb	1100 lb

(U) The thruster designed in these investigations would serve as a backup system for space shuttle attitude control. The technology would also be applicable to the thrust chambers using oxygen/hydrogen propellants.

OXYGEN/HYDROGEN ATTITUDE CONTROL SYSTEM THRUSTERS (C)

PURPOSE (U)

(C) The purpose of this program is to develop a hydrogen/oxygen attitude control thruster for use with a reusable-space-vehicle integrated-ACS feed system. This thruster will differ from the H_2O_2 thrust chamber now under development by TRW for NASA by the fact that it is designed for the reusable-vehicle mission requirements.

PRIOR PROGRAMS (U)

(U) A listing of prior programs in the general field of cryogenic attitude control system technology programs (including the TRW contract) is presented in Appendix A, Section 3.

SCOPE OF WORK (U)

(U) Examine the design problems associated with oxygen/hydrogen thrust chambers, considering both catalyst and spark ignition systems. Particular emphasis should be placed upon service life. Analyze combustion problems.

(U) Conduct necessary component tests. Design and fabricate a prototype thruster. Conduct performance tests and service life demonstrations. Perform tests under required space environmental conditions.

ESTIMATED RESOURCE REQUIREMENTS (U)

<u>Facilities</u>: Captive firing test cell with altitude simulation capability
<u>Schedule</u>: 24 months
<u>Funding</u>: $1,000,000

JUSTIFICATION (U)

(U) Oxygen/hydrogen attitude control systems for the VTOHL have been shown to produce performance improvements from higher specific impulses and greater flexibility from reduced propellant storage restrictions.

(U) The use of oxygen/hydrogen attitude control systems also presents the advantages that the loading and handling of storable propellants are eliminated. The development of the thrusters is an important step towards employment of these improved systems.

VACUUM-JACKETED ALUMINUM LINES FOR CRYOGENIC FEED SYSTEMS (U)

PURPOSE (U)

(U) The purpose of this program is to develop vacuum jacketed aluminum lines principally for use in the fill, drain and feed systems of a VTOHL launch vehicle. The studies will principally be concerned with aluminum lines jointed to stainless steel bellows.

PRIOR PROGRAMS (U)

(U) No contracted exploratory development programs are known to have been conducted in this specific field. However, commercial plumbing with aluminum to steel jointing has been demonstrated.

SCOPE OF WORK (U)

(U) Conduct design and analysis studies in order to establish the requirements for the VTOHL launch vehicle plumbing lines. Establish satisfactory baseline concepts, concentrating on aluminum lines with stainless steel bellows, with some consideration of all aluminum systems.

(U) Fabricate test specimens of aluminum to stainless steel transition joints, and conduct tests to determine tensile and elongation properties, and facture toughness, in oxygen and hydrogen. Evaluate corrosion and contamination problems.

(U) Fabricate test specimens of potentially difficult line sections, such as aluminum-to-steel transition joints and aluminum bellows. Conduct tests in flow loops with liquid hydrogen and oxygen in which thermal and mechanical cycling is performed. Perform the tests to establish the failure limits and the mode of failure.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Cryogenic test cell
Schedule:	12 months
Funding:	$150,000

JUSTIFICATION: (U)

(U) In the past, the large feedlines of cryogenic vehicles have been fabricated of stainless steel. This has been principally because of the thermal expansion, the cycle life of bellows, and to some extent potential corrosion. The weight of the plumbing has not been controlled by the structural properties of the materials, but by the minimum practical gages required for the manufacture of the vacuum jacketed lines.

(U) If aluminum can be substituted for stainless steel in cryogenic plumbing, the higher gages obtained for the same weight can result in significant weight savings. It was determined that the weight savings on the 1-1/2-stage VTOHL vehicle would exceed 3,000 lb.

SURFACE TENSION DEVICES FOR ATTITUDE CONTROL SYSTEM PROPELLANT ORIENTATION (U)

PURPOSE (U)

(U) The purpose of this program is to explore the feasibility of using surface tension devices in the attitude control system (ACS) tanks of reusable space vehicles to orient the propellants for engine operation.

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 7A for a listing of prior programs in the general area of surface tension device technology.

SCOPE OF WORK (U)

(U) Develop attitude control propellant feed system concepts, and establish the requirements for propellant flow rates, etc. Establish surface tension device designs for the systems and the acceleration levels. Examine the effects of sloshing.

(U) Determine means of effectively sealing the surface tension devices. Design the sealed devices in detail. Fabricate scale models of the tanks and the surface tension devices. Using the propellants for which the devices are designed, perform draining and drop tower tests.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Drop tower with provision for small positive accelerations
Schedule:	18 months
Funding:	$250,000

JUSTIFICATION (U)

(U) The attitude control systems require the delivery of propellants under adverse acceleration loadings. Positive expulsion devices, such as bladders and bellows, currently have very limited reusability. Surface tension devices present an attractive approach for propellant orientation from the standpoint of reusability and low maintenance. Additional testing of these devices with various propellants is needed to advance the technology.

EXTENDED-LIFE POSITIVE EXPLUSION BELLOWS (U)

PURPOSE (U)

(U) The purpose of this program is to explore the feasibility of extending the service life of metallic positive-expulsion bellows so that these devices may be used in the attitude control system tanks on reusable space vehicles.

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 7B for a listing of prior programs in positive-expulsion bellows technology.

SCOPE OF WORK (U)

(U) Design positive-expulsion bellows for attitude control tankage. Examine the designs and compare with existing bellows data to determine effects on service life:

- Bellows material
- Propellants
- Material length and sheet thickness
- Design concept

(U) Where existing data are insufficient to permit analysis, fabricate test specimens and test in the expected environments (exposure to propellants, number of cycles, etc.)

(U) Develop the necessary criteria for the development of reusable positive-expulsion bellows.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Hazardous test cell
Schedule:	12 months
Funding:	$100,000

JUSTIFICATION (U)

(U) Positive-expulsion bellows have several possible applications in attitude control systems. The use of integrated attitude control devices requires the employment of some type of pressure rise device (pump, bellows, etc.). This requirement might be fulfilled by some type of refillable bellows expulsion device. Also, the use of attitude control devices in synergetic maneuvers results in requirements to deliver propellants in adverse acceleration levels of up to 0.3 g. In larger tanks, this would require some type of positive expulsion device.

STRUCTURAL ANALYSIS AND OPTIMIZATION TECHNIQUES FOR IRREGULAR LIQUID PROPELLANT TANKS (U)

PURPOSE (U)

(U) The purpose of this program is to develop and verify a versatile structural-analysis computer program that is capable of analyzing any irregularly-shaped propellant tank (i.e., any tank that is not a simple body of revolution).

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 6B for a listing of key programs in the analysis of irregularly-shaped propellant tanks.

SCOPE OF WORK (U)

(U) Conduct a literature search to compile all available data on structural analysis techniques for irregular tankage configurations, such as multicell and segmented 'pillow tank' designs.

(U) Develop a generalized structural-analysis computer program that will calculate stress levels and weight-optimize tank design parameters for any irregular configuration. Verify the model using a typical reusable-vehicle segmented-tank design. Use photoelastic stress analysis and tank-joint-segment structural tests to correlate predicted with actual stress levels.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Structural Test Laboratory
Schedule:	9 months
Funding:	$100,000

JUSTIFICATION (U)

(U) Structural analysis computer programs currently employed in industry require that calculations be performed in a number of steps when irregularly shaped tanks are being analyzed. This is required since only specific regions may be analyzed. A versatile computer program allowing the optimization of entire irregularly shaped tanks would contribute to the advancement of the capability to design reusable vehicles. The program should be capable of optimizing designs.

CHECK VALVE FOR LIQUID FLUORINE SERVICE (C)

PURPOSE (U)

(C) The purpose of this program is to develop a check valve that is suitable for service in the liquid fluorine system for a reusable vehicle such as the cryogenic FDL-5 spacecraft.

PRIOR PROGRAMS (U)

(C) No prior programs are known to have been performed in this specific field. Appendix A, Section 9, lists programs that have been conducted in the general area of space-vehicle fluorine plumbing system components.

SCOPE OF WORK (U)

(C) Analyze the requirements for check valves in reusable space vehicles that use LF_2 oxidizer. Design a prototype valve typical of these requirements and fabricate several test articles.

(C) Conduct gaseous fluorine passivation operations and liquid fluorine compatibility tests on one of the valves. Install another valve in an LF_2 flow loop and conduct cold-flow tests to verify the operating characteristics of the check valve design.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	Fluorine test facility
Schedule:	12 months
Funding:	$200,000

JUSTIFICATION (U)

(C) Technology programs have been developed for several of the critical fluorine components. Check valves are subjected to numerous operations which may affect surface passivation. Development programs have not been performed on check valves for fluorine service and this was identified as a necessary technology program.

8.2.3 General Programs (U)

(U) The "general" programs identified in this study are those which do not fall precisely into the category of technology programs, but which nevertheless contribute to building a base of engineering data from which technology can be developed.

(U) The 3 selected general programs are described on the following pages.

CENTRAL REUSABLE-COMPONENT DATA FILES (U)

PURPOSE (U)

(U) The purpose of the program is to define the need for centralized files of reusable space vehicle component data, and to provide a plan for the implementation of such a data system.

PRIOR PROGRAMS (U)

(U) No prior programs are known to have been conducted in this field.

SCOPE OF WORK (U)

(U) Survey all existing sources of centralized data on aerospace vehicle components, including the Interagency Data Exchange Program (IDEP), the Failure Rate Data Program (FARADA), and the Nonelectronic Reliability Handbook (NEDCO). Evaluate the effects on data availability of the discontinuance of key sources such as the NASA/ Marshall Space Flight Center Parts Reliability Information Center (PRINCE).

(U) Analyze the requirements for component data to be retained and updated continuously in support of reusable space vehicle programs. Formulate a conceptual design of a central data storage and retrieval system for reusable vehicle components. Consider the use of commercial aircraft component-data formats such as the Illustrated Parts Breakdown (IPB) system. Develop an implementation plan for the chosen system, including Government management plans, funding requirements, and schedules.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	(None)
Schedule:	12 months
Funding:	$50,000 (exclusive of annual maintenance costs)

JUSTIFICATION (U)

(U) A survey of component suppliers and aerospace companies has indicated that component design, test, reliability, and lifetime data are rapidly being lost after the completion of development and/or production. Means of accumulation and retention of these data would be a significant contribution to future reusable vehicle programs. Computer indexing techniques could be employed for rapid data recovery.

PROPELLANT SPECIFICATIONS – PROPELLANT AND GAS PURITY/COST TRADEOFFS (U)

PURPOSE (U)

(U) The purpose of this program is to evaluate tradeoffs of increased cost vs improved purity in the as-used quality of liquid propellants and gases for reusable space vehicles.

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 1D, for a listing of prior programs in the general field of liquid propulsion system contamination.

SCOPE OF WORK (U)

(U) Compile an updated survey of the as-used purity of aerospace propellants and gases, using work performed by Rocketdyne on Contract F04611-67-C0085 as the starting point. Establish the quality of propellants as delivered from the manufacturing site, and identify the nature and quantity of contaminants acquired during a typical ground handling cycle (shipping, storage, and transfer).

(U) Analyze the threshold range of damage or hazard to reusable vehicles (e.g., wearout, chemical reactions) arising from contaminants such as water and particulate matter. Determine the applicability of the expendable-vehicle contamination criteria as established on Contract F04611-67-C0085.

(U) Determine the techniques required to improve the manufactured purity for each propellant, as well as the techniques needed to decrease contamination during ground handling (e.g., filtration). Estimate the costs of each approach as a function of propellant purity. Evaluate cost tradeoffs to arrive at an optimum mix of manufacturing and handling improvements that will produce propellants whose as-used purity is within the acceptable range for reusable vehicles.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	(None)
Schedule:	12 months
Funding:	$75,000

JUSTIFICATION (U)

(U) A survey of current propellant specifications indicated that possibly the requirements would have to be increased to assure that levels of contamination, impurities, moisture, etc., are acceptable for reusable vehicles. Other considerations are the employment of propellants from the main propellant tanks for attitude control, power systems, etc.

CONTAMINATION DATA COMPILATION AND EVALUATION (U)

PURPOSE (U)

(U) The purpose of this program is to collect and evaluate sufficient data on the topic of contamination in liquid propulsion systems so as to provide a technology base for future contamination-reduction development programs for reusable space vehicles.

PRIOR PROGRAMS (U)

(U) See Appendix A, Section 1D, for a listing of key prior programs in liquid propulsion system contamination technology.

SCOPE OF WORK (U)

(U) Conduct a search of the literature in the general field of liquid propulsion contamination technology. Concurrently, conduct a survey of key component and subsystem contractors to supplement published references with more recent historical data on contamination.

(U) Collect and evaluate all data. Formulate a Handbook of Liquid Propulsion System Contamination, listing the type and extent of contamination encountered in each of the major liquid propellants in service or planned for use in reusable spacecraft.

(U) Maintain continuous evaluations and surbeys to update the data, retaining all information from space shuttle program developments.

ESTIMATED RESOURCE REQUIREMENTS (U)

Facilities:	(None)
Schedule:	18 months (with continued updating)
Funding:	$150,000 (exclusive of annual maintenance costs)

JUSTIFICATION (U)

(U) Contamination of reusable propulsion subsystems was identified as possibly one of the major operational problems affecting subsystem and component failures. Previous contamination investigations are considered inadequate in the required contamination statistical information. As the development of reusable vehicle subsystems and components proceeds, it is important that data be retained as it is generated.

8.3 RANKING OF THE SELECTED PROGRAMS (U)

(U) Having selected a group of recommended exploratory development programs to support reusable propulsion system technology, it became necessary to rank these programs in order of relative priority so that the most urgent could be performed first. The first step in the ranking analysis was to select criteria that most nearly reflect the relative urgency among programs. The following criteria were selected:

- The extent to which a program resolves a pacing element of technology
- The extent to which a program evaluates a long-leadtime tradeoff among major design alternatives
- The influence that the selected program will have on any concurrent effort in the AFRPL-sponsored engine Advanced Development Programs (ADPs).

(U) Note that, although some of these criteria duplicate the criteria for justification of programs, the emphasis in this analysis was on relative urgency rather than relative merit.

(U) To establish the relative priorities in a systematic manner, a matrix approach was formulated in which the candidate programs were matched against the three ranking criteria described above. A simple three-value rating scale was used to measure the extent to which a given program meets the criteria for each of the three reference vehicle configurations used in this study. By assigning numerical values (3 = major, 2 = significant, 1 = minor) to the evaluation factors, total scores and relative rankings were determined.

(U) The results of the priority ranking analyses for Advanced Technology and Engineering Development programs are presented in Tables 8-1 and 8-2, respectively. It was judged that all three General Programs are of approximately equal priority.

Table 8-1

PRIORITY RANKING – ADVANCED TECHNOLOGY PROGRAMS (U)
(CONFIDENTIAL)

Program	1-1/2 Stage VTOHL			Cryogenic FDL-5			Storable FDL-5			Total	Rank
	Pacing Technology Problem	Key Tradeoff	Project 2 ADP Influence	Pacing Technology Problem	Key Tradeoff	Project 3 ADP Influence	Pacing Technology Problem	Key Tradeoff	Project 1 ADP Influence		
Idle Mode vs low thrust		3	3		3	3				12	1
Oxygen/hydrogen integrated attitude control system		3			3			3		9	2
Leakage detection for reusable vehicles	3			3			3			9	2
Thermal protection system, reusable cryogenic tanks	3			3			3			9	2
Autogenous pressurization vs prepressurization		2	2		2	2				8	3
Replacement of brazed/welded connections	2			2			2			6	4
Fracture mechanics	2			2			2			6	4
Surface tension characteristics	2			2			2			6	4
Liquid sealing of valves	2			2			2			6	4
Ground vent-free oxidizer system				1			3			4	5
Reducing residual propellants	3									3	6

Table 8-2

PRIORITY RANKING – ENGINEERING DEVELOPMENT PROGRAMS (U)
(CONFIDENTIAL)

Program	1-1/2 Stage VTOHL			Cryogenic FDL-5			Storable FDL-5			Total	Rank
	Pacing Technology Problem	Key Tradeoff	Project 2 ADP Influence	Pacing Technology Problem	Key Tradeoff	Project 1 ADP Influence	Pacing Technology Problem	Key Tradeoff	Project 3 ADP Influence		
Minimum-impulse-bit ACS thruster	3			3			3			9	1
Oxygen/hydrogen integrated ACS thruster		3			3		3			9	1
Surface tension devices for ACS	2			2			2			6	2
Extended-life bellows	2			2			2			6	2
Vacuum jacketed aluminum lines	3						1			4	3
Structural analysis of irreg tanks	1			1			1			3	4
LF_2 check valve							3			3	4

Section 9
REFERENCES

1. Lockheed Missiles & Space Company, "Space Transport and Recovery System, Preliminary System Description (U)," LMSC-A914691, 1 February 1968

2. -----, "Orbital Tanker Design Data Study," LMSC-A748410, Contract NAS 8-11326, 30 May 1965

*3. -----, "Reusable Subsystems Design Analysis (U)," LMSC-D080354, 28 August 1968

*4. -----, "Interim Report, An Analytical and Experimental Investigation of Reusable Launch Vehicle Configurations (U)," LMSC-A986485, 20 September 1968

*5. -----, "Advanced Development Program LF_2/LH_2 Maneuvering Satellite Propulsion System," LMSC-A851373, January 1967

*6. Bell Aerosystems, "Maneuvering Satellite Propulsion System Study," SSD-TDR-62-3, March 1962

*7. -----, "Analysis of an Optimum Thrust Modulated Propulsion System for Use in a Space Maneuvering Vehicle," RFL-TDR-64-120, 1964

*8. Rocketdyne, "Maneuvering Satellite Propulsion System Optimization Study (U)," AFRPL-TR-65-252, April 1966

*9. Lockheed Missiles & Space Company, "Advanced Maneuvering Propulsion System, Propellant Feed System Analytical and Design Study (U)," LMSC-687208-I, II, IIIA, IIIB, 30 May 1969

10. -----, Contract NAS 3-7979 Cryogenic Tank Support Evaluation NASA CR-72546 (to be issued)

11. -----, Contract NAS 3-12037, "Fiberglass Supports for Cryogenic Tanks," a 12-month study initiated 12 May 1969

12. -----, Improved Lunar Cargo and Personnel Delivery System," NAS 8-21006, LMSC T-28-68-4, 28 June 1968

---

*Classified information extracted from this document has been incorporated in text material of this Final Report.

13. Lockheed Missiles & Space Company, "Orbital Refueling and Checkout Study," NAS 10-4606, LMSC TI-51-67-21, 12 February 1968

14. -----, "Propellant Selection for Unmanned Spacecraft Propulsion Systems," NAS W-1644, LMSC T-21-69-9, 5 September 1969

*15. Bell Integrated ACS Contract AF 04(611)-10868

16. Masica, William J., and Donald A. Petrash, "Motion of Liquid-Vapor Interface in Response to Imposed Acceleration," NAS TN D-3005, 1965

17. Lockheed Missiles & Space Company, "Orbital Refueling and Checkout Study," LMSC-A838467, 7 November 1966

18. Parker, E. R., Brittle Behavior of Engineering Structures, New York, Wiley, 1967

19. Thielsch, H., Defects and Failures in Pressure Vessels and Piping, New York, Reinhold Publishing Corp., 1965

20. Scrawley, J. E., and J. B. Esgar, "Investigation of Hydrotest Failure of Thiokol Chemical Corporation 260-Inch Diameter SL-1 Motor Case," NASA Lewis Research Center Report, NASA TM X-1194, January 1966

21. Brownfield, C. B., "The Stress Corrosion of Titanium in Nitrogen Tetroxide, Methyl Alcohol, and Other Fluids," North American Aviation Inc., Report No. SID 67-213, March 1967

22. Irwin, G. R., "Crack Extension Force for a Part-Through Crack in a Plate," J. of Applied Mech., Vol 84E, No. 4, December 1962

23. Brown, B. F., and C. D. Beachem, "A Study of the Stress Factor in Corrosion Cracking by Use of the Precracked Cantilever Beam Specimen," Corros. Sci., 5 745-750, (1965)

24. Johnson, H. H., and A. M. Willner, "Moisture and Stable Crack Growth in a High Strength Steel," Appl. Mater. Res., 4, 34 (1965)

25. Brown, B. F., and C. D. Beachem, "A Comparison of Three Specimens for Evaluating the Susceptibility of High Strength Steel to Stress Corrosion Cracking," Inter. Rep. Naval Research Laboratories

26. Brown, B. E., et al, "Marine Corrosion Studies, Third Interim Report of Progress," NRL Memo. Report 1634, July 1965

27. Paris, P. C., and G. C. Sik, "Fracture Toughness Testing and Its Applications," ASTM STP 381, 1965, pp 30-83

28. McClintock, F. A., and G. R. Irwin, "Plasticity Aspects of Fracture Mechanics," Fracture Toughness Testing and Its Applications, ASTM STP 381, 1965

29. Tiffany, C. F., and J. N. Masters, "Applied Fracture Mechanics," Fracture Toughness Testing and Its Applications, ASTM STP 381, 1965, pp 249-277

30. "Cryogenic Materials Data Handbook," Technical Documentary Report No. ML-TDR 64-280, Air Force Materials Laboratory, August 1964

31. Pyle, R., D. E. Schillinger, and C. M. Carman, "Plane Strain Fracture Toughness and Mechanical Properties of 2219-T87 Aluminum and 5A1-2.5 Sn (ELI) Titanium Alloy Weldments and One Inch Thick 5A1-2.5 Sn (ELI) Titanium Alloy Plate," NASA CR-72154, September 1968

32. Tiffany, C. F., P. M. Lorenz, and R. C. Shah, "Extended Loading of Cryogenic Tanks," NASA CR-72252, Undated

33. Lorenz, P. M., "Compatibility of Tankage Materials With Liquid Propellants," Tech. Report AFML-TR-69-99, May 1969

34. North American Rockwell, "A Second Look at the Exponential Assumption for Reliability Estimating," SD 68-490, July 1968

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
LOCKHEED MISSILES & SPACE COMPANY
P.O. BOX 504
SUNNYVALE, CALIFORNIA 94088

2a. REPORT SECURITY CLASSIFICATION
CONFIDENTIAL

2b. GROU [redacted]

3. REPORT TITLE
VOLUME IIA AND IIB – TECHNICAL STUDY REPORT
REUSABLE SUBSYSTEMS DESIGN ANALYSIS STUDY (U)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
FINAL REPORT

5. AUTHOR(S) (First name, middle initial, last name)
Lucian L. Morgan Note: Additional contributors shown in Foreword.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1970	574	34

8a. CONTRACT OR GRANT NO.
F0 4611-69-C-0041

b. PROJECT NO.
N/A

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
AFRPL TR-69-210

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
none

10. DISTRIBUTION STATEMENT
In addition to security requirements which must be met, this document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of AFRPL (RPORT/STINFO) Edwards, California 93523

11. SUPPLEMENTARY NOTES
N/A

12. SPONSORING MILITARY ACTIVITY
USAF ROCKET PROPULSION LABORATORY
EDWARDS, CALIFORNIA 93523

13. ABSTRACT

ABSTRACT (U)

(U) Volume II, Parts A and B, contains the details of the approaches, analyses, evaluations, results, and conclusions from the performance of the seven tasks: Task 1 – Selection of Vehicles and Missions; Task 2 – Vehicle Design Extension; Task 3 – Extension of Subsystem Analyses; Task 4 – Determination of Subsystem Requirements; Task 5 – Reusability of Existing Hardware; Task 6 – Subsystem Tradeoffs; and Task 7 – Advanced Technology Recommendations.

(U) Task 1 presents the detailed definition of the baseline vehicles and missions. Task 2 provides a detailed description of the subsystems and presents analyses and evaluations of these. Task 3 indicates the results of the examination of certain problems related to reusable vehicles and their operations. Task 4 provides the detailed requirements derived for the subsystems with regard to total active and inactive life, component cycles, acceptable leakages, and acceleration loadings. Task 5 presents the results of the examination of the identified subsystem components and their requirements with the objective of determining if currently existing hardware is applicable. Task 6 indicates the selected subsystems and the reasons for their selection. Finally, Task 7 provides the selected technology programs and presents relative priorities for their accomplishment.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Reusable Space Transportation Subsystems						
Propulsion Subsystem Requirements						
Propulsion Subsystem Analyses						
Reusable Space Vehicles						
Launch Vehicles						
Space Missions						
Reusable Vehicle Requirements						
Reusable Tankage, Insulation, Components, etc.						
Subsystem Tradeoffs (Reusable)						
Systems Effectiveness Analysis						
Advanced Technology for Reusable Vehicles						

UNCLASSIFIED
Security Classification